Connecting Spaces and People with Location-Based Augmented Reality Game Design - An Empirical Study

Yasas Sri Wickramasinghe
yasas.wickramasinghe@pg.canterbury.ac.nz
HIT Lab NZ, University of Canterbury
Christchurch, New Zealand

Heide Karen Lukosch
heide.lukosch@canterbury.ac.nz
HIT Lab NZ, University of Canterbury
Christchurch, New Zealand

James Everett
jameseverett@nianticlabs.com
Niantic Aotearoa NZ
Wellington, New Zealand

Stephan Lukosch
stephan.lukosch@canterbury.ac.nz
HIT Lab NZ, University of Canterbury
Christchurch, New Zealand

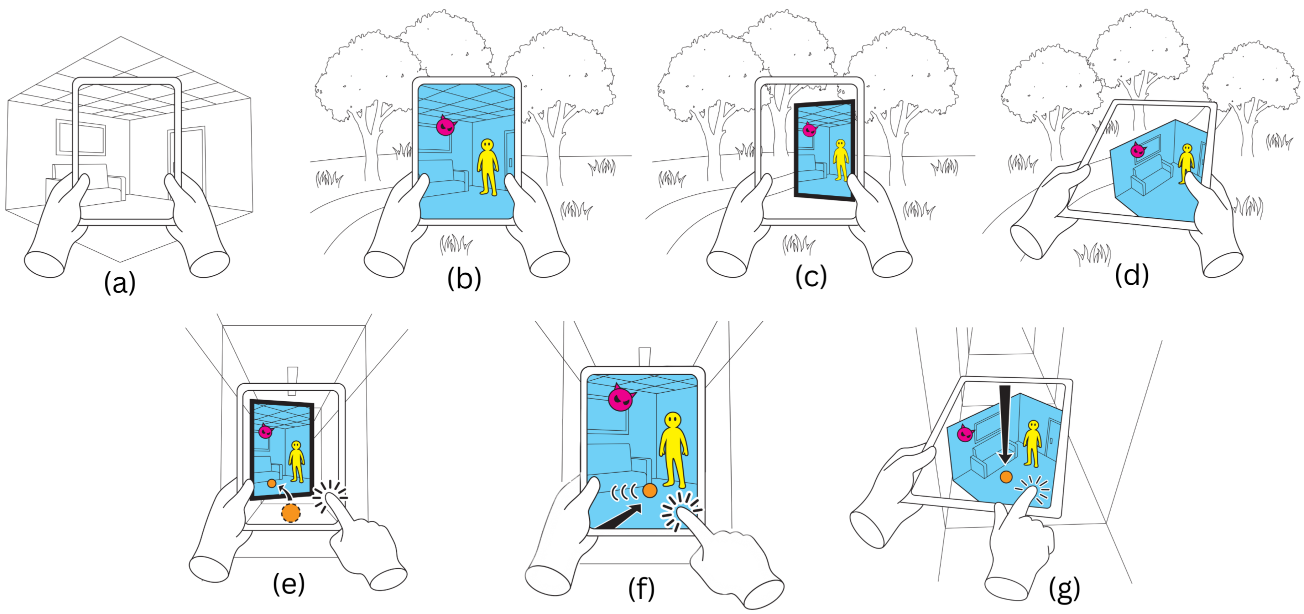

Figure 1: The game design and modes of resource sharing between spaces (a) Using LiDAR for scanning surroundings. (b) Representing scanned space in window mode. (c) Representing scanned space in tabletop mode. (d) Representing scanned space in overlay mode. (e) Sharing virtual objects from the local space to the remote space via window mode. (f) Sharing virtual objects from the local space to the remote space in overlay mode. (g) Sharing virtual objects from the local space to the remote space in tabletop mode.

ABSTRACT

Location-based augmented reality games (LBARGs) allow for interaction with the physical environment of a player. Studies show that a significant portion of LBARGs fail to fully utilize the potential of the physical environment but instead treat augmented reality (AR) as a mere gimmick. Therefore, we investigated AR game mechanics that incorporate the player's location. We identified three modes, i.e., tabletop, overlay, and window, to represent a player's location and, based on these, designed a LBARG including novel game mechanics to foster spatial presence and immersion. We recruited 32 participants (n=32) and evaluated their experience with the different modes. The results suggest that the chosen game mode significantly impacts the players' spatial presence and highlights game mechanics that utilize the physical environment, and help

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to connect remote spaces and people. Our findings can guide future game designers on how to design for spatial presence and immersion within LBARGs.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; *User studies.*

KEYWORDS

location-based game, spatial presence, remote multiplayer, game design

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1 INTRODUCTION

Location-based games (LBGs) provide game experiences that leverage the player's indoor or outdoor environment through networked interfaces, offering ways to interact with the physical world during play [25]. LBGs can use Augmented Reality (AR) [29] to turn real-world locations into playgrounds, providing players with meaningful experiences [23]. For example, LBARGs such as Pokémon GO [33] and Harry Potter: Wizards Unite [36] use AR to add virtual content on top of the real world and also build a fictional narrative around the virtual content.

Lately, AR, in conjunction with game mechanics that allow to travel through portals to virtual locations in Harry Potter: Wizards Unite game [36] or interact with virtual game creatures through AR views in games like Pokémon GO [33] and Jurassic World Alive [28] have been used to create location-based gameplay experiences. However, most existing LBARGs use AR more as a novel feature than as a functional game element [2]. According to Laato et al. [23], the meaningfulness of playing LBARGs is influenced by both in-game factors as well as real-world factors including the gameplay location. In relation to this, current LBARGs miss the opportunity to meaningfully incorporate the gameplay location into the game [9, 23].

While current LBARGs utilize the environment to initiate, maintain, and support the game, they do not make use of the location's unique characteristics within the game. Consider a LBARG which takes place at an outdoor park that requires water from a nearby pond that can be used as a game artifact to extinguish a virtual fire within the game. Such LBARG could involve participants physically exploring the surroundings to gather virtual resources, such as water, and collaboratively using AR to pass these resources between players. We envision to expand the boundaries of current location-based play by allowing multiple players to share their gameplay locations with each other. We assume such game elements could enhance the meaningful use of the players' location.

The study by Morschheuser et al. [30] investigated how collaborative game features affect different forms of group dynamics. Their results show that collaborative game features induce collective commitment of a group of individuals to participate in a collaborative action. Being able to translate features of gameplay locations and share it with other players could thus enhance the meaningfulness of location-based augmented reality multiplayer games (LBARMGs). However, it is unclear how to create play that makes meaningful use of multiple locations in a multiplayer game.

We identify spatial presence [55], and immersion [10] as two important constructs in this study. Schubert [46] explains spatial presence as the result of unconscious spatial perception processes that aim to determine the location of a person in relation to their surroundings and the potential interactions with it. Immersion has been identified as a critical factor in understanding the continuation of playing LBARGs like Pokémon GO [27]. Moreover, when players feel a strong sense of spatial presence and immersion, their interactions with other players and the game environment may become more genuine and enjoyable, enhancing the overall meaningfulness of the collaborative play [11, 54]. Therefore, we focus on creating more meaningful and collaborative LBARGs by exploring these factors and using a location's unique characteristic to create play. Hence, within this paper, we focus on the following research question (RQ):

- RQ: How can a LBARG be designed to represent the location of one player to another remote player within the game while fostering spatial presence and immersion of remote players?

To answer our RQ, we created a LBARG, which requires remote players to find resources at their locations and to help other remotely connected players. Using our game design, we compared three ways of connecting remote locations using different AR designs. In a within-subjects user study with 32 participants, we evaluated the game design using qualitative and quantitative measures. Each participant evaluated our proposed game mechanics with regard to spatial presence, augmented reality immersion, and user experience and shared further gameplay experience in a semi-structured interview. Based on this, the major contributions of this paper are:

(1) Novel game mechanics to make use of a player's location
(2) Different designs for representing a remote location in a LBARG
(3) Recommendations on how to foster spatial presence and immersion of remote players

In the following, the paper reviews related work on the current state of the LBGs and identifies limitations in existing LBARGs. Then, it presents the methodology of our study including the game design followed by an in-depth analysis of the qualitative and quantitative results. In the end, we present our findings and discuss their implications for the design of future LBARGs.

2 RELATED WORK

2.1 Current State of Location-Based Games

Previous research [19, 41, 48] has explored popular LBGs, and studies [18, 22] have categorized them. This section provides an overview of these different types of LBGs and outlines their design implications.

Several researchers have identified LBGs as a type of game that provides a distinct gaming experience compared to other games by combining the real-world environment of the players with a virtual one [38, 48]. These games are designed to use the players' physical environment, either indoor or outdoor location, in the game through networked interfaces [25]. Other studies have shown that LBGs can promote social interactions, learning, and game engagement [20, 25].

LBGs, like Pokémon GO [33], make players interact with the real world around them. At the outset of Pokémon GO's popularity, Koskinen et al. [19] have studied the self-reported measures of players and discovered that they often recalled encounters (*"memorable moments"*) with other game players and the particular locations they visited while exploring the environment. Recognizing the degree of interaction with the environment, Kiefer et al. [18] categorized LBGs into three main types - spatially discrete, spatially continuous, and mixed-form. This classification helps to understand how players engage with their environment in different ways within LBGs.

According to the classification by Kiefer et al. [18], the spatially discrete LBGs refer to a gaming experience where gameplay is tightly coupled to a specific, physically defined location. Players are required to be at a specific place to play this type of game. These games may employ GPS, mapping software, or AR features to create game experiences for players. Geocaching [12] is an example of this category because players need to visit specific physical locations to find geocaches and sign the logbook. Spatially discrete LBGs are popular due to their ability to consume virtual and real-world elements, creating a unique and engaging form of entertainment [18].

Following the same classification by Kiefer et al. [18], unlike the spatially discrete, the spatially continuous LBGs allow players to navigate the real world while engaging with the game. These games are not tightly coupled to a specific geo-location. However, due to the nature of this type of game, players may require some assistance to navigate through mini-maps or visual cues. Additionally, the game may change game dynamics according to the present place of the player using GPS or AR features [18]. "Can You See Me Now" [3] is an example of this category.

Some LBGs combine features from both types, which can be identified as a mixed form as identified by the same classification by Kiefer et al. [18]. The "Zombies, Run!" game [1] is an example of this type because the game integrates elements of both spatially discrete and spatially continuous gameplay. Players start the game at a specific physical location, which serves as a *"home base"*. During the run, players receive audio cues about zombies chasing them, motivating them to increase their pace. Virtual items can be collected during the run, and the player's progress is tracked using GPS. While the starting point is spatially discrete, the ongoing gameplay is spatially continuous, combining both types of experiences.

While existing LBGs excel in using the players' physical location to foster social interactions and engagement, they do not allow players from remote locations to join and collaborate in the local location-based game world. The above classification proposed by Kiefer et al. [18] illustrates the diversity of LBG experiences, yet it also underscores an opportunity for the development of multiplayer LBGs that go beyond the co-located LBGs. By allowing players to engage in gameplay without being bound by geographical proximity, a new genre of LBGs opens up, offering innovative ways for connecting with each other and their locations. This idea is also supported by the finding from Papangelis et al. [39] study, which acknowledges the perception of a location in a game and human territoriality have the potential to significantly influence engagement and motivation to play LBGs using mobile phones.

2.2 Challenges in Remote LBARG play

Games such as Pokémon GO [33], Ingress [32], and even board games such as Catan in AR [52] are LBARGs that allow multiplayer gameplay. While Ingress and Catan in AR require all players to be physically present at the same place to play, some efforts have been made to play LBARGs remotely, such as the Remote Raid feature in Pokémon GO [4]. This section briefly describes such efforts, how players perceived those features, and the challenges of designing remote LBARGs.

2.2.1 Location-Based Play During the Pandemic. Due to the global social distancing measures prompted by COVID-19 in 2020 and physical location-based play being challenged, AR game developers had to make several changes to ensure that players continue to engage with their LBARGs [4]. Examples of these changes include the "Remote Raid Battles" [31] feature in Pokémon GO and the "Knight Bus" [5] update to the Harry Potter Wizard Unite (HPWU) Game.

In Pokémon GO, Raid Battles happen at special locations called Gyms where strong Pokémon, known as Raid Bosses, appear with a timer. Players team up with other physically nearby players to defeat the Raid Boss together, and if successful, they have a chance to catch it and get rewards. After introducing remote raid passes [31], players could purchase raid passes. These features were designed to alleviate the restrictions imposed by social distancing and lockdowns, allowing players to continue playing the game from home [4].

Similarly, the ability to remotely fight with others in fortresses is called the Knight Bus in HPWU. When players tapped the "Knight Bus" button on the map, they were virtually transported to a Fortress located at Hogwarts Castle. This was a different game mechanic from the usual gameplay, where Fortresses were tied to real-world locations previously.

In a co-design session conducted by Bhattacharya et al. [4], researchers observed that players were interested in incorporating at-home play activities in addition to physical displacement. The participants appreciated a virtual "home portal" that would enable resource acquisition without interfering with the game's strategic dynamics. This was similar to the Knight Bus in HPWU, which could be accessed from anywhere in the game world.

However, on the other hand, changes made to LBARGs during the pandemic led to some problems. One of them was falsifying GPS location, also known as "Spoofing" [21]. Pokémon GO is designed to allow players to join raid battles happening at nearby locations without physically being at the exact location. However, some players found a way to fake their mobile phone's GPS location and tricked the game, and joined remote raids happening almost anywhere in the world. According to Laato et al. [21], there was also a subreddit (*"/r/pokemongospoofing"*) posting about cheating in Pokémon GO by spoofing location.

Another challenge observed due to the remote raids in the game relates to players' safety. Even though the remote raid feature was introduced by the Pokémon GO developers during the pandemic, the game still encouraged going out to a remote location to a certain degree. The player community has raised concerns about this considering the ethical considerations regarding player safety, especially during a pandemic period like COVID-19 [21].

Prior to the pandemic, one of the appealing features of LBARGs was its connection to historical landmarks and other fascinating locations that players would visit [21]. During the pandemic, many players wanted to play the game in these locations, even by connecting to them remotely [21]. However, current LBARGs do not allow players to see and connect with remote locations in AR without physically being there. Bhattacharya et al.[4] suggest that, in a post-pandemic world, novel design ideas may emerge that move LBGs in new directions. They highlight the need to explore the applicability of remote gameplay elements to a broader player base and consider how to holistically leverage interactions between real-world places and people supporting meaningful LBG experiences.

The above discussion shows that there is a desire to experience LBARGs being remotely connected. Furthermore, in line with the insights provided by Bhattacharya et al. [4], we are of the opinion that the integration of remote locations and players in the real-world may foster unique and meaningful gaming experiences.

2.2.2 Representing Remote Locations in AR. Partala et al. [40] explored the use of AR in tourism using a tablet-based AR experiment with participants. They used a realistically sized 3D model of a tourist attraction, Mannerheim's Saloon Car, near the actual landmark in Finland. Although a tablet device was used for the experiment, the authors acknowledge that the participants rated relatively high scores for spatial presence. According to the authors, their results suggest that a good spatial presence and user experience can be delivered in similar AR experiences where users can walk inside a 3D model using a tablet device.

As discussed in the previous section, the evolution of LBARG play, game design adaptations during the COVID-19 pandemic, underscores the importance of spatial presence in connecting remote locations and players. The desire for virtual travel, cultural exploration, and enhanced social connections within games like Pokémon GO highlights the potential for AR to bridge physical distances and create shared virtual spaces [4]. Partala et al. [40] found that measuring the spatial presence of remotely connected places using AR becomes a critical aspect of this exploration, offering a way to quantify and understand the remote gameplay. Their finding can also guide the design of future LBARGs, ensuring that they not only facilitate remote play but also enrich the gaming experience by connection across remote locations.

2.3 Place Attachment in Location-Based Games

Place attachment acts as an emotional link individuals establish with a particular place [7, 14, 26]. Oleksy et al.[37] confirmed that LBGs can increase place attachment. Their study suggests that the more engaged the players are with the game and the more they interact with others, the stronger their emotional connection to the game environment becomes. Their research has focused on Pokémon GO and has investigated how various aspects of playing LBARGs can affect place attachment to the gameplay environment. The same study also found that satisfaction with playing and social interactions made during play positively predict place attachment.

Wang and Hsieh (2020) [53] studied Pokémon GO gameplay experience from multiple perspectives. They have uncovered the affection that players build toward a certain place due to the game. They further explored the relationship between human interaction via media entertainment and affectional connections to physical places. Their findings highlight the complexity of human-environment relationships in LBARGs and emphasize the need for further exploration of place attachment, spatial presence, and the integration of physical and virtual locations in LBGARGs.

Previous studies[7, 14, 26, 37, 53] on place attachment provide a strong foundation for understanding the emotional bonds players form with physical places through gameplay and offer valuable insights for designing and implementing remote LBARG play that fosters unique and meaningful gaming experiences.

2.4 Summary

Exploring remote LBARG play has revealed opportunities and limitations, particularly in fostering spatial presence and immersion through AR. Building upon these insights, the following section presents our approach to designing and implementing remote LBARG play enabling players to engage meaningfully with remote locations and remotely connected players.

3 GAME DESIGN

3.1 Representing a Remote Location in a LBARG

Stafford et al. [49] found that the AR tabletop perspective, which presents virtual objects on a real-world surface, supports collaborations between multiple users indoors and outdoors. According to the same study, presenting a bird's-eye view-like perspective in LBGs can facilitate the spatial understanding of crowd movements, and Stafford et al. [49] also argue that the perspective allows for a comprehensive and intuitive representation of the environment and enables users to effectively assist individuals on the ground level in navigating and comprehending their surroundings. Therefore, we chose an AR tabletop view as our first game mode.

Similarly, another study[51] found that AR overlay views, which present virtual objects of the same size as the real environment, can enhance players' feeling of experiencing a more natural environment in AR. Other studies [15, 42] denote that the ability to move through virtual environments and overall spatial awareness can be improved by incorporating virtual environments on a room-scale or real-world-a-like scale. Ruddle et al. [42] looked into the effectiveness of using either table-scale or room-scale AR applications for learning. They anticipated that if individuals can roam freely within a large-scale AR environment, the spatial understanding of their experience would be enhanced. Though their results were not significant, they showed that the size of the AR content and environment can alter the degree of spatial presence. Therefore, we identified an AR overlay mode as the second game mode to study.

Portals are a relatively new, effective element to make transitions between virtual environments seamless, and they have helped achieve a higher presence within virtual reality transitions between multiple environments [16]. Furthermore, Husung et al. [16] have shown that portals can create a sense of connection between real and virtual spaces and foster a higher presence during in-game transitions between virtual environments. Even though portals are so far studied mainly in the virtual reality domain, in our opinion, introducing a game mode in AR to provide a sense of connection between distributed gameplay locations may have an effect on engagement and presence, and the overall gameplay experience. Therefore, we recognized AR window mode as the third game mode, reflecting its distinctive attributes within the context of AR.

The selection of remote location representation modes in our game design is guided by the above studies in the field, drawing on established principles and empirical findings to inform the design of our study. We named these modes the AR tabletop mode, AR overlay mode, and AR window mode.

We identified three different game modes in AR for sharing locations in real-time (Figure 2). Each modality of the game design is chosen carefully to understand how these game modes affect the overall play. Figure 2 shows these three game modes in our game design.

Figure 2: Screenshots of the game design. From left to right: window mode, overlay mode, tabletop mode

3.2 Game Scenario

Our game design facilitates player roles as the "*local player*", and the "*remote player*". These two players are not co-located. The local player in the game plays while connected to the remote player. The remote player allows the local player to connect to their location as described in the section 3.3. In order to elicit a thorough understanding of the influence of user experience, immersion, and spatial presence, we kept the game scenario consistent across the three game modes and introduced an automated Non-Player Character (NPC) as the remote player for our study.

We designed the game scenario as a representation of a fictional room for the remote player, asking the "*local player*" to help the "*remote player*" to fight enemies. The local player can see the remote player's location and the enemies in their surroundings. The local player must perform some in-game tasks to help the remote player, e.g., collecting certain artifacts to help the player fight their enemies. An illustration of the entire game scenario, including these in-game tasks, is presented in Figure 3.

3.3 Location-sharing Between Remotely Connected Players

The game design requires the local and remote players to exchange 3D scans of their respective physical locations to initiate a game session. We used Niantic Lightship Scanning Framework [35] to create textured 3D scans of the surrounding spaces using LiDAR-enabled handheld devices. In the context of this experimental game design, the local player is placed in an outdoor environment while the remote player is situated within an indoor space. Scans of the remote player's environment had been pre-produced for the study.

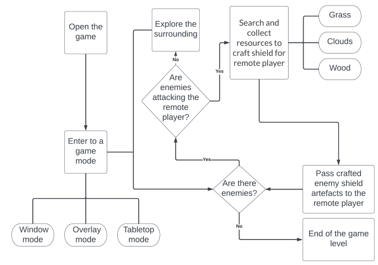

Figure 3: Flow diagram of the game scenario

3.4 Multiplayer Roles in the Game

The distinction between the roles of local and remote players lies in their responsibilities within the game. The local player needs to collect resources, craft in-game objects, and share them with the remote player, helping to fight enemies. Local player plays from an outdoor space meanwhile the remote player connects and shares an indoor space. Figure 4 further explains the interactions between multiplayer roles.

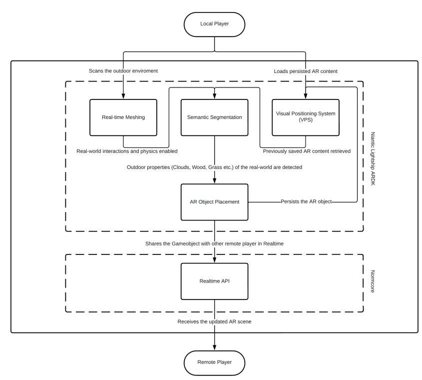

Figure 4: High-level architecture diagram of the experimental game design

In the gameplay, both players are presented with randomly generated flying enemies that pose a threat to their survival. The remote player is equipped with the ability to throw water balls with their superpowers to counteract these enemies. However, in order to effectively utilize this ability, the remote player needs help from the local player to craft water balls.

The player designated as the local player is responsible for exploring their outdoor environment to gather necessary resources such as wood, grass, and clouds, which are incorporated into the game mechanics. The collected resources are then transferred to the remote player via AR, which can be achieved through any game mode. This game design allows for the integration of real-world elements into the gameplay. In multiplayer scenarios, if the remote player lacks certain resources, the remote player can obtain them from the local player, who has collected them from their physical environments. This feature emphasizes the collaborative aspect of the game and encourages players to work together to achieve their objectives. Figure 5 presents screenshots of occasions where the local player is requested to collect resources by scanning real-world physical properties to help the remote player under attack.

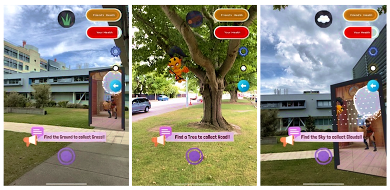

Figure 5: Screenshots of the resource collection phase. From left to right: The local player is requested to find grass, then wood, and then clouds

3.5 Technical Implementation

We designed our game focusing on handheld mobile devices as its primary platform and incorporated real-time networking capabilities for remote player connectivity. The game's development was done using the Unity3D game engine [50] due to its compatibility with the chosen AR development kit, Niantic Lightship ARDK [34]. This development kit was selected to provide essential features for our LBARG, such as real-time meshing for instantiating virtual objects on real-world surfaces, semantic segmentation for understanding properties of a location such as grass, trees, and clouds, and a visual positioning system (VPS) for anchoring sharable AR content to the real-world locations, which are necessary components in the game's design. Furthermore, real-time sharing of AR content and environment is another necessary game design requirement for which we used the Normcore library [17]. Table 1 shows the minimum system requirements for Android and iOS device models to run the game.

Table 1: Minimum system requirements

Component	Specification
Processor	A12 Bionic, Samsung Exynos 990, Snapdragon 865, or the latest version
RAM	4GB or more memory
Storage	500MB or more storage
Operating system	iOS 11, Android 7 (API level 24), or the latest version
Sensors	Accelerometer, GPS, Gyroscope, LiDAR sensor (optional but recommended)
Internet connectivity	1Mbit/s or higher bandwidth

4 EXPERIMENT DESIGN

After obtaining ethics approval from the Human Research Ethics Committee (HREC), we conducted a user study comparing the three game modes. This section details our user study, how we used mixed methods for the evaluation, the participant selection, and the evaluation instruments we used.

We carried out a user study in a within-subject repeated measures design where each participant experienced all three game modes. Participants were asked to provide specific feedback on the different game modes, and their feedback was compared.

4.1 Participants

We recruited 32 participants (n=32) who responded to the study advertisements shared on public notice boards and social media. Two participants had to be excluded from the final sample, as they were identified as outliers due to low questionnaire completion times and contradicting answers to reverse-coded questions. The remaining sample of 30 participants was used for subsequent analysis and interpretation of the study results.

The gender distribution skewed slightly towards female participants, with 19 female (63.3%) and 11 male (36.7%) respondents. Age distribution was relatively balanced across the younger age groups, with 7 participants aged between 18-24 (23.3%), 8 participants each in the 25-29 and 30-34 age groups (26.7% for each), and 7 participants in the 35-40 age bracket (23.3%). Prior experience with AR was common among participants. A majority of 25 participants (83.3%) reported having some form of AR experience, while only 5 participants (16.7%) reported no previous AR experience.

4.2 Measures Used for the Evaluation

The measures used in this study are the Spatial Presence Experience Scale (SPES) [13], the Augmented Reality Immersion (ARI) Questionnaire [10], and the short version of the User Experience Questionnaire (UEQ-S) [45]. These were chosen to capture participants' experiences with the game modes and their level of spatial presence, AR immersion, and user experience.

4.2.1 Spatial Presence Experience Scale (SPES). The SPES [13] is selected to evaluate the level of spatial presence elicited by the AR game modes. This validated eight-item questionnaire uses a five-point Likert scale ranging from 1 (= I do not agree at all) to 5 (= I fully agree). The questionnaire considers spatial presence as a two-dimensional construct, including self-location (SL) and users' possible actions (PA).

4.2.2 Augmented Reality Immersion (ARI) Questionnaire. The ARI questionnaire[10] is chosen to evaluate the level of AR immersion experienced by the participants. This questionnaire includes 21 questions on a seven-point Likert scale ranging from 1 (= Strongly disagree) to 7 (= Strongly agree). Items in this questionnaire are categorized into six factors: interest, usability, emotional attachment, focus of attention, presence, and flow. As we identify immersion as an important factor to measure in our game design, this multi-faceted questionnaire collectively assists in evaluating the immersion.

4.2.3 Short Version of the User Experience Questionnaire (UEQ-S). We decided to use the UEQ-S [45] because it requires less time to complete than the full version of the UEQ [24]. Participants need to respond to eight items that evaluate the pragmatic quality, i.e., supportiveness and easiness of the experience, and hedonic quality, i.e., users' pleasure or fun experiences.

4.2.4 Semi-structured Interview. The aim of the interview was to create a deeper understanding of the experience and the preferences of the participants and to be able to triangulate them with quantitative measures.

During the interview, participants were asked questions on presence and immersion, e.g. "Based on your experience with all three game modes, which one did you enjoy the most? Why?", usability and interaction, e.g. "Were there any game modes you found more challenging to use or understand? Why?", collaboration and place immersion, e.g. "How did you feel about playing the game in the remote player's shared place? Why?". We also asked further questions, such as why the participant performed some specific game action instead of doing it in another way, to understand some reasons behind in-game actions during the user study session.

4.3 Procedure

Firstly, participants received a brief explanation of the study's objectives and requirements. Following this, they were presented with the information sheet and consent form, providing an opportunity for any clarifications or questions. Once participants signed the consent form, the study commenced.

After completing a brief demographic survey, participants were guided to a safe outdoor area, equipped with an iPad running our game design. Each participant engaged in the game for three different game modes. We used partial counterbalancing to randomize the order of the game modes presented to each participant. Each game required participants to scan real-world elements like the sky, grass, and wood to collect resources for in-game artifacts. Once these resources were acquired, participants shared their crafted game objects within the shared AR space by double-tapping on the screen. Following task completion, participants provided feedback through a questionnaire. After completing all game modes, participants ranked their preferences and engaged in a semi-structured interview to express their overall impressions and comments on the game design.

5 RESULTS

In this section, we present the results gathered from the user study. Our results focus on (1) Spatial Presence Experience, (2) Augmented Reality Immersion, (3) User Experience, and (4) Qualitative Results from the interviews, including preferred game modes, participants' feedback, and observations during the experiment.

5.1 Spatial Presence Experience

As part of the data analysis, the internal consistency reliability of the SL and PA scales was assessed via Cronbach's alpha [6], providing insights into the reliability of these measures. Furthermore, the study calculated the Pearson's correlation coefficient between SL and PA among participants, investigating how these two facets of spatial presence are interconnected. Table 2 shows these reliability and correlation values.

The internal consistency of both the SL and PA scales, as evaluated through Cronbach's alpha, was found to be high, with values of 0.922 and 0.881, respectively. This suggests that the items within each scale were measuring the same underlying construct consistently, and thus, it can be inferred that the SPES was a reliable instrument in the context of the current study. Furthermore, a strong positive correlation (r = 0.759) was observed between the mean scores of SL and PA. This indicates that participants who felt a stronger sense of being in the gaming environment also perceived a greater capability to perform actions within this virtual setting. This correlation underscores the interconnectedness of SL and PA within the spatial presence experience.

Table 2: Correlation and Cronbach's alpha values for the SPES items

Measure	Value
Cronbach's alpha for Self-Location	0.9224065
Cronbach's alpha for Possible Actions	0.8810312
Pearson Correlation between Self-Location and Possible Actions	0.7586119

Next, we performed descriptive statistics to gain an initial impression of how game modes differ from each other with spatial presence values. Figure 6 shows participants' responses to the SPES questionnaire.

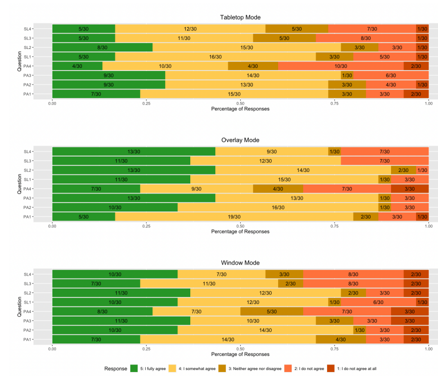

Figure 6: SPES Responses for Three Game Modes

The questions assessed the extent to which participants felt self-located in the game environment. In general, participants responded favorably to the SL questions across all modes. Most responses gravitated towards "*I somewhat agree*" and "*I fully agree*", indicating a high degree of perceived spatial presence.

The PA questions evaluated how interactive the participants found the game environment. Responses to the PA questions were more diverse. In particular, the latter statement ("*PA4 - "It seemed to me that I could do whatever I wanted in the environment of the presentation"*) received a considerable number of negative responses ("*I do not agree at all*" and "*I do not agree*") in all three game modes. The diverging stacked bar chart (see Figure 6) allow for a clear visual comparison of the distribution of responses within each game mode. The results of the descriptive statistical tests, as shown in Figure 7 show that the values for SL and PA are higher for the overlay mode compared to the tabletop and window modes.

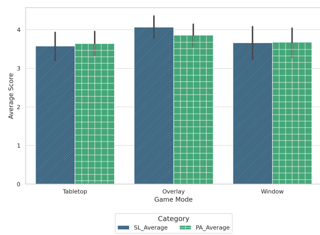

Figure 7: SPES Average Scores by Game Modes

The Shapiro-Wilk test was conducted to assess the normality of the distributions for SL and PA average scores. The W statistic for the SL average scores was approximately 0.918, and the p-value was 2.95×10^{-5}. The W statistic for the PA average scores was approximately 0.914, and the p-value was 1.79×10^{-5}. In both cases, the p-values were significantly less than 0.05, leading us to reject the null hypothesis of normality. Therefore, we discovered that the distributions of the SL and PA average scores are not normal. Therefore, we performed the aligned rank transformation (ART) and then repeated measures of ANOVA. The results revealed significant main effects of both the type of question (SL vs. PA, $p < 0.001$) and the game mode ($p = 0.038$), suggesting that both of these factors significantly influence the responses of the participants.

Given the non-normal distribution of both the SL and PA average scores, non-parametric statistical methods were employed. The Friedman test [47], which is a non-parametric alternative to the one-way ANOVA with repeated measures, was used to investigate the differences in the average scores across the three game modes.

From the statistical analysis, we observed significant SL average scores across the game modes (SL1: $X^2(2) = 8.5882, p = 0.01365$; SL2: $X^2(2) = 6.8197, p = 0.03305$; SL3: $X^2(2) = 8.4941, p = 0.01431$; SL4: $X^2(2) = 7.6418, p = 0.02191$). ***These results suggest that the game mode significantly impacts the SL of the players.***

However, no significant differences were found in the PA average scores across the game modes (PA1: $X^2(2) = 0.35294, p = 0.8382$; PA2: $X^2(2) = 2.3929, p = 0.3023$; PA3: $X^2(2) = 2.0822, p = 0.3531$; PA4: $X^2(2) = 1.9487, p = 0.3774$). Therefore, it can be inferred that the game mode does not have a significant effect on the PA of the players.

These findings provide an in-depth understanding of the impact of game mode on player experience, indicating that the game modes we implemented directly impact the SL of the players in shared gameplay spaces in the LBARG developed.

Post-hoc Nemenyi tests [8] were conducted to ascertain the game modes that significantly impact the average SL and PA scores. ***The results revealed a significant difference in the SL scores between the tabletop mode and the AR overlay mode*** ($p = 0.0068$). However, no significant differences were discerned between the tabletop mode and the AR window mode ($p = 0.4375$), or between the AR overlay mode and the AR window mode ($p = 0.1671$).

For the PA scores, the post-hoc tests did not discover any significant differences between the game modes. These results indicate that the game mode significantly influences the players' sense of SL, particularly when contrasting the tabletop mode with the overlay mode. On the contrary, the game mode does not seem to significantly affect the PA perceived by the players.

5.2 Augmented Reality Immersion

The reliability score, Cronbach alpha of 0.9268723 indicated very high internal consistency. This means that the items in the questionnaire are closely related to each other and likely measure the same underlying construct.

The descriptive statistics performed on the ARI questionnaire resulted in the findings as shown in Figure 8. These boxplots show the median, interquartile range (IQR), and overall range of scores for each category across the three game modes. The results showed that the values for the "Engagement", "Engrossment" and "Total Immersion" are higher for the overlay mode compared to the tabletop and window modes. This suggests that participants felt a stronger involvement in the game (engagement), had a greater feeling of being attached and involved in the game (engrossment), and had a greater feeling of being immersed in the game environment (Total Immersion) when playing in the overlay mode.

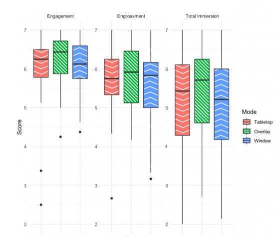

Figure 8: Box plots showing ARI scores for each game mode

Density plots, as shown in Figure 9 showed all game modes have positive skewness. This indicates that the data is not normally distributed. However, we conducted a Shapiro-Wilk test to further validate whether the dataset is normally distributed or not. The p-values obtained from the Shapiro-Wilk test for the three categories (engagement, engrossment, and total immersion) indicated that the distributions of the average scores in all three categories deviate from a normal distribution. The p-values for all categories are less than the threshold of 0.05, which leads us to reject the null hypothesis of normality.

The Kruskal-Wallis H test was used to compare the median scores across the three game modes for each category. This test ranks all the data from all groups together and then compares the sum of ranks between the groups. However, Kruskal-Wallis tests revealed no significant differences in engagement ($p = 0.679$), engrossment ($p = 0.624$), or total immersion ($p = 0.617$) across the three game modes. This can be due to various factors, including sample size and noise or the sensitivity of the measurements. However, the descriptive statistics provide a number of valuable findings to discuss further.

5.3 User Experience

The UEQ-S results (Figure 10) provided valuable insights into the comparative performance of the three game modes: tabletop, overlay, and window. Below, we present findings from the UEQ-S under the two constructs: Pragmatic Quality and Hedonic Quality.

Figure 9: Density Plots for Engagement, Engrossment, and Total Immersion across Game Modes

The pragmatic quality scale assessed the practical aspects of the game modes. The window mode achieved the highest mean score (2.117), followed by the overlay mode (2.025) and the tabletop mode (1.833). These results suggest that users found the window mode to be the most user-friendly and effective in terms of achieving the intended goals. The overlay mode also demonstrated a high level of functionality, although slightly lower than the window mode. The tabletop mode, while still receiving a positive score, lagged slightly behind in terms of user-perceived functionality and ease of use.

The overlay mode achieved the highest mean score (2.058) for the hedonic quality scale. This was closely followed by the tabletop mode (1.775), with the window mode presenting a slightly lower score (1.750). These findings suggest that users found the overlay mode to be the most enjoyable and interesting, offering a stimulating and engaging experience.

The overall user experience, a combination of both pragmatic and hedonic qualities, saw the overlay mode achieving the highest mean score (2.042). The window mode followed closely (1.933), and the tabletop mode had a lower mean score (1.804). This indicates that the users had the most positive overall experience with the overlay mode, which effectively combined functional effectiveness and enjoyment. The window mode, despite its high pragmatic quality, fell slightly short in providing an equally high overall experience, potentially due to its lower hedonic quality score.

Figure 11 compares three modes using the benchmark scores of the UEQ analysis. The UEQ benchmark dataset consists of data from 21,175 individuals in 468 studies, covering various products such as business software, web pages, web shops, and social networks [43]. The benchmark chart allows for comparing results with the benchmark data, providing insights into the relative quality of our

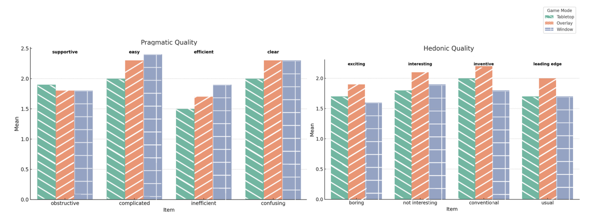

Figure 10: UEQ-S Responses for Pragmatic and Hedonic Items

game design to other products. Overall, it is visible that all three game modes had excellent benchmark scores.

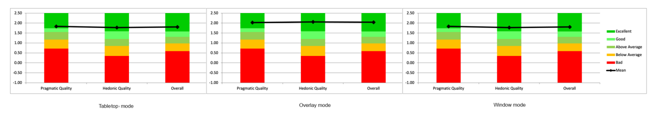

Figure 11: UEQ-S Benchmark Results

5.4 Qualitative Results

This section presents qualitative feedback gathered from the interviews. We report on the interview feedback here together with the researchers' observations during the experiment regarding the different game modes explored in the study. We discuss the primary themes, participant quotes, and observations that directly relate to the game design.

5.4.1 Preferred Game Modes. The majority of participants, 20 out of 30 (67%), stated that the overlay mode was their preferred game mode when asked in the first interview question. This was followed by the window mode, which was the favorite for 9 participants (30%). Only one participant preferred the tabletop mode. This preference pattern aligns with our quantitative findings, where the overlay mode scored the highest on spatial presence, augmented reality immersion, and user experience.

5.4.2 Theme 1: Novelty of the Game Design. The participants' feedback consistently emphasized the novelty of the game design. P12 mentioned the novel design of the game as one explanation for their experience. Immersion and physical activity were also mentioned as contributing factors.

> *"Actually, in the overlay [game mode], the more that I feel immersed in the game. Because it's quite different than those [other games] I have played before." - P12*

This sentiment was echoed by both P15 and P19, who stated,

> *"I think it's very interesting because rather than sitting at one place when you go and when you collect the wood and everything which is around you, yes, very inventive." - P15*

> *"I enjoyed the overlay one the most because it felt the most immersive." - P19*

Furthermore, P30 highlighted the potential for real-time voice communication between players, adding an extra layer of immersion by stating,

> *"If I can maybe hear her[remote player] and, then she says, Hey, I need some grass here, I need some wood here. Maybe it will help me motivate more to look faster or gather resources faster. I wouldn't know which one to prioritize." - P30*

The window mode was appreciated for its unique incorporation of real-world elements. This mode's emphasis on blending the virtual and real worlds contributed to its appeal, and participants suggested potential avenues for further integration.

"Comparing to the other two, the portal [window mode] feels like my friend's space is also part of my real world. So the more like connected, right, the other two games in a feeling is I'm doing my job in this outdoor environment. Yes. And then their world is just an object. So they actually feel more disconnected compared to the portal." -P6

P23 suggested that different game modes could be integrated within a single gameplay session, which is an interesting point for future design considerations.

> *"I felt like it could have been maybe interconnected into a game, so maybe at first it starts with the portal [window mode] and then after you unlock something you can actually walk around in the play mode." - P23*

5.4.3 Theme 2: Physical Activity and Engagement. Participants showed interest in being able to interact with their surroundings physically. Furthermore, they mentioned positive feedback about the meaningful use of their location within the game (across all three game modes). These game mechanics prompted participants to move around, collect resources, and perform actions to help the remote player.

> *"I was actually doing walking and physical activity [...] I felt very, like lost in the game. If that's a term. I have to avoid the enemies. So, I have to move in that direction. And they have to collect something, so I have to move in that direction. Because that's where the tree is, that's where the sky is, that's where the grass is. So it felt natural. I didn't think about it consciously that I'm actually walking." - P30*

> *"I was kind of interested if like particular motion paths are more efficient for collection. So the last time I tried like a circular motion, I felt like that was a little bit more efficient than moving side to side. It was still kind of fun. Just yeah, try trying out which one is more efficient." - P23*

In conclusion, the qualitative data provides a rich context to our quantitative findings and offers valuable insights for future improvements and iterations of the game.

6 DISCUSSION

This section discusses our findings and provides recommendations on how to design for spatial presence and immersion within remote locations in a LBARG. Our quantitative results are summarized in Table 3.

6.1 How to Represent a Remote Location of a Player to Another Remotely Connected Player within a LBARG?

The results revealed that the game mode significantly impacts the SL of the players in remotely shared gameplay spaces in a LBARG according to our game design. However, the game mode did not significantly affect the PA of the players.

The overlay mode demonstrated higher mean values for engagement, engrossment, and total immersion compared to the tabletop and window modes, suggesting a stronger sense of being in the game environment and an elevated feeling of being able to interact with the game environment. Further statistical analysis revealed that the choice of the game mode significantly impacts players' sense of SL. This was particularly noticeable when comparing the tabletop and overlay modes. The overlay game mode consistently outperformed the tabletop and window modes in terms of spatial presence, as evidenced by higher SL and PA scores. Participants felt more self-located within the game environment and perceived a greater capacity to perform actions when engaging with the overlay mode. This finding also supports the claim by previous studies [15, 42] that virtual environments at a room-scale or real-world-alike scale can improve spatial awareness and movement in virtual environments.

The interviews also showed how the overlay mode stimulates players' interactions with their surroundings. Participants' expressions, such as feeling *"immersed"*and *"I didn't think about it consciously that I'm actually walking"* underscore the efficacy of the overlay mode's design in intensifying players' engagement and involvement. Consequently, the qualitative data complements and reinforces the quantitative insights.

Regarding user experience, the overlay mode again achieved the highest overall score. Despite its very high pragmatic quality, the window mode fell short in providing an equally high overall experience, potentially due to its lower hedonic quality score.

In summary, our findings suggest that LBARGs should not only facilitate remote play but also enrich the gaming experience by connecting players across remote locations. The overlay mode, offers a promising direction for achieving this, potentially fostering higher spatial presence and immersive gaming experiences in AR by bridging physical distances.

6.2 Make Use of the Real-world Resources in the Game

We designed a game that required the gathering of real-world resources such as grass, wood, and clouds to create in-game objects that are essential for advancing in the game. The local player must collect these items from their environment and then pass them to the remote player, as shown in Figure 1 (e), (f), and (g).

Each game mode allowed players to pass these crafted game objects differently. The window mode lets passing objects by simply throwing the virtual object through the window from the local location to the remote location. In the overlay mode, players must first walk into the remote location from their local surroundings and then share the object with the remote player. The tabletop mode requires players to point their handheld device at the miniaturized remote location and then drop the virtual object from above.

Table 3: Mean and Standard Deviation (SD) results for Spatial Presence Experience Scale (SPES), Augmented Reality Immersion (ARI), and Shorter Version of the User Experience Questionnaire (UEQ-S) for each condition. UEQ-S scores range from -3 to +3, SPES scores are on a 5-point Likert scale, and ARI scores are on a 7-point Likert scale.

Questionnaire	Subscale	*Tabletop*		*Overlay*		*Window*	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Spatial Presence Experience Scale (SPES)	Self -Location	3.58	1.11	4.07	1.02	3.66	1.28
	Possible Actions	3.64	1.17	3.86	1.09	3.68	1.26
Augmented Reality Immersion (ARI)	Engagement	6.00	0.972	6.2	0.670	6.08	0.702
	Engrossment	5.66	0.857	5.82	0.870	5.52	1.12
	Total Immersion	5.05	1.38	5.33	1.30	4.98	1.38
User Experience Questionnaire (UEQ-S)	Pragmatic Quality	1.83	1.158	2.025	0.968	2.117	0.911
	Hedonic Quality	1.77	1.097	2.058	0.953	1.750	1.281

Participants frequently praised the overall game design for its novelty, with statements like *"It felt like an evolution in gaming,"* and *"I've never experienced anything quite like it in gaming before."* This sentiment highlights the potential for LBARGs to expand the boundaries of traditional gaming, merging the real world with the virtual in ways that captivate players.

The window mode achieved slightly higher values from the pragmatic quality items in UEQ-S, meaning players have found this mode to be an effective way to reach their goal in the game, helping the remote player by sharing resources. Therefore, the window mode could be suitable for designing similar games that require players to exchange real-world resources between remotely connected locations using AR.

6.3 Recommendations on How to Design for Spatial Presence and Immersion within Remote Locations in a LBARG

Based on our results, we have identified the following recommendations for LBARGs that connect remote locations and people with a high degree of spatial presence and immersion:

1. **Prioritize the Overlay Mode for Spatial Presence and Immersion**: Based on our results (see Table 3), the overlay mode provides players with a stronger sense of being in the game environment and a greater feeling of being able to interact with it. Therefore, when designing LBARGs to foster spatial presence, we recommend to use the overlay mode.

2. **Incorporate Real-World Resources into the Gameplay**: The game design included a novel game mechanic to make use of the player's location. Players had to search and collect resources from real-world and share them with the remote player, helping to fight enemies. The ARI results show that all three game modes had high scores for engagement, engrossment, and total immersion. Similarly, all game modes scored highly on the UEQ-S when considering the UEQ benchmark dataset [44]. The participants' qualitative feedback specifically highlights the use of real-world resources as engaging game mechanic. Therefore, we recommend to incorporate real-world resources into the LBARG design to connect the virtual and physical worlds and facilitate player engagement.

7 LIMITATIONS AND FUTURE WORK

The results derived from our study are subject to some limitations: First, the sample size of 32 participants who attended the study might be too small to generalize the findings to a larger population. As we mentioned in our discussion section, some post-hoc tests with the variables engagement, engrossment, and total immersion gave higher p values comparing different game modes. A higher participant count might lead to comparing the three modes further and finding more insights about each of the design approaches.

Second, we used a tablet device for the experiment. Therefore, the recommendations might not be applicable to similar future game designs targeted to run on head-mounted displays. It may require further studies to understand player perception and experience of these game modes on other devices.

Third, we used an NPC for our game, mocking the remotely connected player. This design choice was made for consistency across all conditions. However, if there was a real player instead of the NPC connecting from the other side, empathy and other human factors might have some effect on the game experience. We plan to take this factor into account in future studies. Furthermore, integrating real-time communication between players could enhance the overall player experience.

Finally, we consider combining modes and studying the player experience in the future. For example, the window mode acting as a transition interface between the real world and overlay mode would be interesting to study. Another interesting observation is that participants used the term "portal" to describe the window mode. 8 participants even tried to walk into the remote space through the AR window. Therefore, we plan to conduct further studies addressing these limitations and introduce multiplayer game elements connecting more than 2 players at once, based on the findings of this study and further meaningful AR game mechanics.

8 CONCLUSION

In this work, we presented a novel LBARG design that facilitates multiplayer interaction from remote locations. We also shared our empirical study's findings, including quantitative and qualitative insights. Through the investigation of three game modes - tabletop mode, overlay mode, and window mode - the research provides valuable insights into the varying levels of spatial presence, immersion, and user experience across these modes. These findings can guide the design of future LBARGs, offering a new perspective on how to connect spaces and players in different locations.

Moreover, the research has addressed another gap in the current literature on LBARGs, which often fails to incorporate the environment's unique characteristics into gameplay. By focusing on fostering spatial presence and immersion for both local and remote players, the study provides recommendations for creating LBARGs that incorporate properties of gameplay locations.

In conclusion, our study has revealed that the choice of game mode significantly influences players' sense of spatial presence in remote locations. Additionally, incorporating real-world resources into gameplay, facilitated by AR features, can add novelty to LBARGs, bridging the gap between physical and virtual spaces. Our study affirms the potential of LBARGs in connecting remote spaces and players, particularly in the overlay mode, which exhibited high levels of engagement, engrossment, and total immersion. By combining the strengths of the overlay and window modes, and incorporating real-world resources, LBARGs can be developed to offer even more connected gaming experiences between spaces and players. This research opens up new possibilities for LBARG design, offering a new way to explore remote places in a playful way. The findings of this study can potentially influence future LBARGs' design, fostering spatial presence, immersion, and user experience.

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