Is Any Room Really OK? The Effect of Room Size and Furniture on Presence, Narrative Engagement, and Usability During a Space-Adaptive Augmented Reality Game

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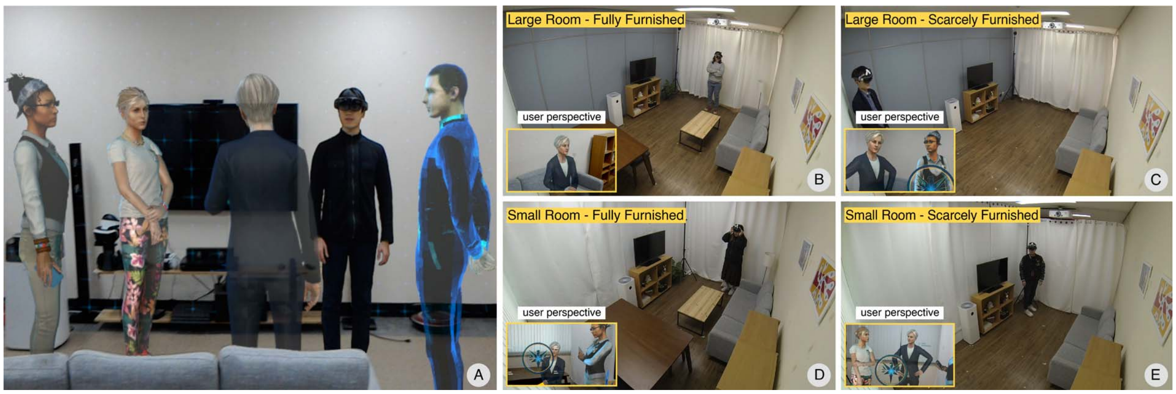

Figure 1: In this study, we compare the gameplay experience of Fragments in four types of spatial settings. The images depict how the same Holocall scene from the game (A) is seen differently by the participants playing in each study condition: (B) Large Room - Fully Furnished; (C) Large Room - Scarcely Furnished; (D) Small Room - Fully Furnished; and (E) Small Room - Scarcely Furnished.

Abstract

One of the main challenges in creating narrative-driven Augmented Reality (AR) content for Head Mounted Displays (HMDs) is to make them equally accessible and enjoyable in different types of indoor environments. However, little has been studied in regards to whether such content can indeed provide similar, if not the same, levels of experience across different spaces. To gain more understanding towards this issue, we examine the effect of room size and furniture on the player experience of Fragments, a space-adaptive, indoor AR crime-solving game created for the Microsoft HoloLens. The study compares factors of player experience in four types of spatial conditions: (1) Large Room - Fully Furnished; (2) Large Room - Scarcely Furnished; (3) Small Room - Fully Furnished; and (4) Small Room - Scarcely Furnished. Our results show that while large spaces facilitate a higher sense of presence and narrative engagement, fully-furnished rooms raise perceived workload. Based on our findings, we propose design suggestions that can support narrative-driven, space-adaptive indoor HMD-based AR content in delivering optimal experiences for various types of rooms.

Index Terms: Human-centered computing—Human computer interaction (HCI)— HCI design and evaluation methods—User studies; Human-centered computing—Ubiquitous and mobile computing—Ubiquitous and mobile computing design and evaluation methods

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1 Introduction

Augmented Reality (AR) has emerged as a novel and innovative medium for storytelling [31, 36, 44]. Its core characteristic, which lies in its ability to merge the real world with the virtual world, presents unprecedented possibilities for contemplating, designing, and experiencing narratives. In the beginning, storytelling in AR had primarily been focused on enhancing the experience of storybooks [1] and journalistic print media [36], such as magazines and newspapers. With the introduction of mobile devices, the domain took a turn to explore opportunities in augmenting the experience of physical spaces through virtual content. More recently, continuous advances in the development of Head Mounted Displays (HMDs) and tracking technology (e.g. SLAM and depth sensing) [20] has led to content that enables narratives and their virtual representations to actively incorporate detailed spatial traits of indoor environments.

In this context, narrative content delivered through AR HMDs and experienced indoors is garnering much attention as the most groundbreaking form of storytelling that the AR platform can as yet offer at a commercially feasible level. That a certain narrative experience can adapt to different types of spaces shows much promise in establishing AR as a unique narrative medium. Consequently, a major issue concerning the development of this particular type of content lies in how the physical indoor space can best be considered to guarantee similar levels of experience for anyone, anywhere. In order for this type of content to gain wide traction as a viable form of storytelling, the relationship between the virtual narrative space, the physical space, and the user situated among these co-existing spaces must be carefully investigated and determined [34].

978-1-7281-4765-9/19/$31.00 ©2019 IEEE
DOI 10.1109/ISMAR.2019.00-11

Regarding this topic, past studies have looked into how properties of narrative space and physical space can be combined to create an augmented space [28], where synchronizing the virtual and real is perceived as essential in creating impactful narratives for AR [38,41]. Other works discussed various factors of user experience and how they are influenced under different conditions in AR or Virtual Reality (VR) [2, 29, 35, 43]. Additionally, some studies focusing on the space-adaptive features of narrative-driven AR content have explored how AR content can better respond to the layout of indoor spaces they are being experienced in [11, 14, 33]. However, much remains to be uncovered in terms of how specific spatial conditions in indoor environments affect the virtual construction of narrative spaces and how they are experienced by users wearing AR HMDs.

In order to address this gap in research, we report on a user study that examines the effect of room size and the amount of furniture during the gameplay of Fragments[1], a commercially available game for the Microsoft HoloLens[2] that currently represents the category of narrative-driven, space-adaptive indoor content for AR HMDs. Participants of the study were subject to a between-subject experiment where each of them played the game in one of four room types: (1) Large Room - Fully Furnished; (2) Large Room - Scarcely Furnished; (3) Small Room - Fully Furnished; and (4) Small Room - Scarcely Furnished, as is shown in Figure 1. We assessed their ratings on factors of presence, narrative engagement, and usability while keeping track of their movements during the game.

Study results showed that the users' sense of presence and narrative engagement are higher when the narrative content is experienced in large rooms. In addition, the perceived workload for this type of narrative experience is heavier in a small space filled with furniture. These results were associated with how the participants perceived and reacted to the mapping of the virtual narrative space over the physical space, which differed in each study condition.

Based on the findings from our study, this paper makes the following contributions:

- An in-depth understanding of how changing the size and density of indoor spaces can lead to different levels of presence, narrative engagement, and usability while experiencing narrative-driven, space-adaptive content for AR HMDs

- Design implications that suggest possible directions on how the spatially adaptive features of such narrative content can be controlled to maximize their effect

2 Background

In this section, we review related literature across three areas: (1) virtual narrative space and physical space in AR; (2) presence, narrative engagement, and usability in AR; and (3) space-adaptive narrative content for AR. We then summarize these works to derive our hypotheses.

2.1 Virtual Narrative Space and Physical Space in AR

In the field of narratology, narrative space is defined as "*the place or places within which the situations and events are represented...and the narrating instances occur* [37]." In the context of more traditional mediums of storytelling, such as written text, narrative space was not deemed as essential as the temporal aspects of a story [4]. Rather, it was perceived as a mere background that was to be taken for granted as the series of events unfolded [18]. However, the rise and proliferation of digital media have shed new light on the discourse of narrative space as a core component of storytelling. In computer games, specifically, narrative has been discussed not only in terms of how the sequence of a story progresses in time, but how their visual representations are framed and positioned in a virtual space that pulls the player in from the other side of the screen [6, 45].

The term is becoming all the more imperative in narrative content for AR, because through this new medium, the once-separated narrative space of the virtual realm shifts to reality and coexists with the immediate physical space that the reader/viewer/player is in [26, 27]. Consequently, attributes of the physical environment that house the virtual narrative space have become just as important in defining and designing AR narratives [25]. Central to the study of physical spaces across disciplines–media theory being one of them–has been the concept of the sense of place [8]. The sense of place is constructed through three components of place identity, as defined by Relph [39], which are: physical setting, activities afforded by the place, and meanings and affect attributed to the space.

In AR, these three elements join the virtual narrative space and the physical space to create an augmented space, as proposed by Manovich et al. [28]. Augmented spaces provide dynamic, localized narrative elements that can be interacted with in a person's immediate surroundings, thereby reinforcing the sense of place. Previous work has aimed to understand trends in the development of narrative content for augmented spaces. In their survey of AR games, Shilkrot et al. [41] found that the implementation of narrative-based AR applications are often met with the need for a stronger connection to the spaces they are being used in. In another study, Pyae and Potter [38] created an engagement model for AR games in the context of Pokemon Go. Their model highlights that it is important for both the real and virtual worlds to be synchronized during the gameplay. However, these studies have not ventured further beyond the formative stage of providing the theoretical grounds for AR narratives and stating the importance of considering the spatial environment they are realized in.

2.2 Presence, Narrative Engagement, and Usability in AR

Presence refers to the subjective instinct of being transparently connected to a media experience [9], or "*the perceptual illusion of non-mediation* [24]." In a state where a high level of presence is achieved, the interface between the content and the user becomes invisible and seamless [46]. The concept of dramatic presence, which is defined as the feeling of being in a dramatic situation caused by sequential events [19], also provides a relevant framework to our study of narrative-based AR experiences. In an AR environment, erasing the interface to the point of transparency and staying in the drama is a difficult challenge because the interface is what links and maps the virtual space to the real one [27]. Thus, supplying a sufficient amount of real world context to match the augmented experience in creating a 'mental imagery space' mapped over both spaces can help dissolve the interface and raise the level of presence in AR [3].

The challenge becomes more evident when presence in AR is compared to that in VR. AR environments require the user to be cognizant of both the virtual and the real simultaneously. In the VR domain, however, presence is regarded as a state where the user feels completely dissociated from the real world [10,32], which seemingly renders the task of being present within a narrative experience as relatively effortless. Contrary to the notion that presence can better be achieved in VR, Tang et al. demonstrated that the discrepancy between the actual and virtual body in VR can lead to a decrease in presence, whereas AR allows for more natural body movements and thus does not impede the sensation in this regard [43]. In fact, being able to perceive one's own body move to its own accord can elevate the sense of self presence, which is a subcategory of presence as put forth by Biocca [3]. However, the implications of these studies have not been tested for narrative-driven, indoor AR content for HMDs.

Narrative engagement deals with a somewhat different aspect of being engrossed in the content from the sense of presence. Dow et al.

[1] `http://www.asobostudio.com/games/fragments`
[2] `https://www.microsoft.com/en-us/hololens`

[9] assert that presence is not a prerequisite to narrative engagement, for it refers to the degree of interest or involvement in the content or activity of an experience, as opposed to the feeling of 'being there' in the situation. Nonetheless, there lies a blurry line between definitions and measurements of narrative engagement and presence, and overlaps are often found in them. Busselle et al. [5] combine terminologies from both sides in devising a quantitative rating scale for narrative engagement, which include factors such as narrative presence and emotional engagement. The ARI questionnaire by Georgiou et al. [12] uses engagement as a subscale for measuring immersion during the use of location-aware AR applications.

Consequently, narrative engagement during AR experiences can only be subject to a similar kind of dilemma that presence is faced with in that the influence of the physical space on the co-existing narrative space must be mediated for it to reach and maintain a high level. Few prior studies have dealt directly with how conditions of the physical space affect this factor. In spite of this, Nordin et al. [35] found that the more the real world environment is visibly integrated to Mixed Reality(MR) games, the less the degree of engagement and immersion is achieved by conducting two user studies that manipulated the spatial conditions accordingly. Although this work provides valuable insight on which we can ground our study, the conditions tested did not involve the size or the composition of physical indoor spaces.

The usability of applications refers to the ease of use and quality of experience they provide [30]. It is related to a wide range of factors, such as the hardware the application operates on, software performance and interface, the environment, and the users. In the AR domain, Ko et al. [22] specified the usability features of mobile AR applications as display device, multimodal interface, methods of manipulation, and the movement of users on the go. Over mobile devices, the usability of AR games that involve moving around in physical space was found to decrease when users had too many distractions in their surroundings [7]. Whether this holds true for indoor HMD-based experiences in a more restricted space has not yet been studied.

Turning to AR experiences on HMDs, McGill et al. [29] reported that the presence of other people or objects and their closeness to the user impede usability. Another recent study stresses the importance of securing sufficient physical space for the user to perceive and interact with virtual objects, especially when spatial mapping is involved [15]. In the same study, sudden changes in the real space, such as people passing by or objects being added or removed, were also found to have a negative effect on the AR application's usability. All these works provide a useful direction from which we can consider how the conditions of indoor spaces might impact the usability of an AR narrative content through HMDs.

2.3 Space-adaptive Narrative Content for AR

Due to advances in tracking technology, AR is now capable of utilizing features of the physical space in the experiences they create. In the case of mobile devices, ARKit[3] (Apple iOS) and ARCore[4] (Android) libraries enable their respective smartphone apps to use SLAM, which maps the real environment while keeping track of the player's movement within it. This form of tracking also offers features to make AR experiences more immersive, such as recognizing objects and images in the user's environment and responding to real-world lighting conditions. Key examples of narrative-based content that incorporate the surrounding physical space through plane and object detection over these platforms are Alice in Wonderland AR Quest[5] and Wonderscope[6]. These applications place the narrative elements of different stories in the user's vicinity and present the story accordingly.

For HMDs, the employment of depth cameras for 3D geometry reconstruction allows for more sophisticated and spatially adaptive ways to create and experience AR narratives for indoor spaces. Spatial mapping is made possible by performing room scans that enable a deeper understanding of the physical space than is possible on the aforementioned mobile platforms. Through this function, virtual objects are augmented on real surfaces while utilizing real world depth cues, such as occlusion. Current state-of-the-art devices that take advantage of spatial mapping are AR HMDs such as the Microsoft HoloLens, the MagicLeap[7], and Meta 2[8]. Narrative-driven content designed for these types of devices and use spatial mapping include Holotour[9], Fragments, and Luna[10]. They commonly provide fictional experiences by transforming indoor spaces to stage virtual tours or interactive games.

In the past, some studies have explored how such AR applications can understand the makeup of physical spaces and appropriately position virtual objects around them. Galantay et al. [11] presented an AR installation designed to study interactive, space-oriented AR-scenarios in an indoor setting. More recently, Guo et al. [14] developed an indoor pervasive game for MR played in the context of everyday life, which involved players interacting with and reorganizing physical objects employed in a virtual game. In addition, Nagata et al. [33] suggested a system that automatically adjusts to its surroundings by scanning the environment with HMDs like the HoloLens. However, much is left to be uncovered regarding how the conditions of physical space configure in the design and experience of such content.

2.4 Summary and Hypotheses

An extensive survey of related work revealed four implications to be followed up in our current study. First, active bodily movements of the user in an AR environment may lead to a higher sense of presence. Second, measures to make the link between the physical space and the virtual narrative space can raise presence. Third, the visibility of real surroundings during AR experiences may impact narrative engagement negatively. Fourth, too much information in the surrounding physical space can decrease the usability of AR content.

In line with the above summary, we hypothesize as follows:

- H1. The sense of presence during a space-adaptive, narrative-driven indoor AR HMD experience will be higher in large spaces.
- H2. The sense of presence during a space-adaptive, narrative-driven indoor AR HMD experience will be higher in a room with many furniture items.
- H3. Narrative engagement with a space-adaptive, narrative-driven indoor AR HMD content will be lower in a room with many furniture items.
- H4. The perceived usability of a space-adaptive, narrative-driven indoor AR HMD content will be lower in small, cluttered spaces.

3 Study Design

3.1 Conditions

Our study was conducted with Fragments, which is a narrative-driven, space-adaptive indoor AR game for the Microsoft HoloLens. We chose this game as the testing ground for our study because it embodies the common direction and goal of AR narratives for indoor environments to be experienced on optical see-through AR

[3] https://developer.apple.com/arkit/
[4] https://developers.google.com/ar/
[5] https://itunes.apple.com/us/app/alice-in-wonderland-ar-quest/id1279423433?mt=8
[6] https://wonderscope.com
[7] https://www.magicleap.com
[8] https://www.metavision.com
[9] http://www.holoforge.io/work/holotour
[10] https://www.magicleap.com/experiences/luna

HMDs: On its official website, it states that its mission is to provide "compelling new possibilities for storytelling and gameplay" in "whichever room you play [42]." A key function provided by the HoloLens, spatial mapping is used in the game to adapt to room size, present context-aware characters, and thereby enable emotional storytelling at a state-of-the-art, commercially available level.

Fragments is a first-person crime-solving game that puts the player in the role of an investigator, who is required to track down a kidnapper on the loose by examining various types of clues augmented in the physical room the player is experiencing the game in. Before the actual gameplay begins, the game scans the physical space so that it can determine where to spatially place virtual content: In short, the augmented game space is adapted to the physical space. For instance, life-sized Non-Player Characters (NPCs) take notice of the real furniture by sitting on them or going around them when they move, and some virtual clues are augmented on top of physical objects or placed around the space created between separate pieces of furniture.

As we wished to understand the effect of room size and the amount of furniture on player experience, we designed a between-subjects study in which the first level (Memory 1: First Dive) of Fragments was played under four different spatial conditions: (1) Large Room - Fully Furnished; (2) Large Room - Scarcely Furnished; (3) Small Room - Fully Furnished; and (4) Small Room - Scarcely Furnished. The first level was chosen to be played in the study as it serves both as a gameplay tutorial and an introduction to the overarching narrative of the game. Furthermore, it also showcases the defining characteristics of Fragments in its close link between the physical space, the augmented space, and narrative progression.

3.2 Setup

The size of the large room was $4.8 \times 3.2m$ ($15.36m^2$), whereas the small room was a reduced version of the large room, measuring at $3.9 \times 2.6m$ ($10.14m^2$). The sizes of the rooms were determined so that they were both large enough to be sufficiently synced with the game space; otherwise, the game would not proceed to the next step. At the same time, there had to be a clear difference in which their sizes were generally and relatively perceived. This was accomplished by setting the area of the large room to be 1.5 times larger than the small room. We selected a vacant office room on campus to set up and experiment all conditions by blocking off the space according to the predefined measurements for both room sizes.

The furniture items in the rooms for all conditions were selected and arranged to recreate a typical living room environment. The Fully Furnished rooms in both size conditions included 12 pieces of furniture: a sofa, a coffee table, a flatscreen TV, a TV stand, two bookcases, a dining table, two dining benches, a lamp, a plant, and an air purifier. On the other hand, the Scarcely Furnished rooms featured just half of the furniture in the Fully Furnished ones, with only the sofa, the flatscreen TV, the TV stand, the two bookcases, and the air purifier left intact and rearranged according to room size. Additionally, HTC Vive Base Stations[11] were placed to track the participants position during the experiment in two opposite corners of the rooms at all times, along with a GoPro camera installed near the ceiling at one corner to record the participants' activities. Figure 2 depicts the setup of all four study conditions for the user study.

3.3 Dependent Variables

Based on our research questions and hypotheses, we evaluated six dependent variables–presence, narrative engagement, game usability, perceived workload, task completion time, and distance traversed–as factors of player experience in this study. To measure the participants' experience of presence in the augmented game environment, we used a modified version of Witmer et al.'s Presence Questionnaire

[11]https://www.vive.com/eu/accessory/base-station/

Figure 2: The setup of four study conditions based on room size and the number of furniture

(Version 3.0) [47]. Three items on audio fidelity were dropped, as all the sound components of the game are presented in the same way regardless of the spatial conditions it is played in. Consequently, a total of 29 items on a 7-point Likert scale regarding involvement, sensory fidelity, adaptation/immersion, and interface quality were evaluated.

We examined the degree to which participants engaged themselves with the game's narrative through the Narrative Engagement Scale, which was devised by Busselle and Bilandzic [5]. Narrative understanding, attentional focus, emotional engagement, and narrative presence were measured across 12 7-point Likert scale items. Items pertaining to narrative presence differed from items of the Presence Questionnaire in that they asked for the level of self-assessed presence within a space created and maintained by a story.

In order to rate how at ease the participants felt in each condition during the game, we employed two widely-used scales: The Post Study System Usability Questionnaire (PSSUQ) [23] and the NASA Task Load Index (NASA TLX) [17]. The PSSUQ evaluates system usefulness, information quality, and interface quality through 16 items that focus on the experience of interacting with a wide range of systems designed to perform specific tasks. The NASA TLX was used in our study to examine the degree of physical and mental strain participants experienced during their gameplay. We opted for the 'raw TLX' [16] approach and forewent the weighting process to obtain perceived workload scores ranging from 0 to 100.

Lastly, task completion time and distance traversed were respectively defined by the seconds and meters it took from the participants' initiation of Memory 1: First Dive (signalled by the participant selecting the 'Play in Living Room' button) to the moment the stage was completed (marked by captions that read 'Saving'). Both factors were measured with a Vive Tracker[12] attached to the HoloLens, which recorded the current timestamp, position, and orientation at the top of each participant's head every second. The distance was calculated by adding the difference between each timestamped position recorded during the defined task completion time.

[12]https://www.vive.com/eu/vive-tracker/

3.4 Participants

We began the study with a total of 45 participants who were students and university personnel recruited on campus. While none of them were native English speakers, they all had a high level of fluency to the extent that they could understand and follow the game, which is entirely in English, without any difficulty. To eliminate the possibility that significant differences in the participants cognitive abilities may act as an underlying factor in the outcome of the experiment, participants were all subject to a 15-minute-long Continuous Concentration test provided by TestMyBrain.org[13] for research uses [13].The Continuous Concentration test was specifically chosen as the test tool because it evaluates three subcategories of cognitive ability: analogical reasoning, concentration (attention), and memory. Since these are the core cognitive skills required to play Fragments, we felt that this test was most suited to our purpose. The test score results uncovered no outliers among the participants, as there were no significant differences in all of their scores across the four study groups ($F(3, 36)$=.069, p=.976).

At the end of the experiment, however, the data of five participants were excluded due to unforeseen circumstances that disrupted the experimental procedure (e.g., hardware malfunction and errors in the instruction) and critically affected the participants' gameplay. Conclusively, the final sample consisted of 40 participants, whose ages ranged from 23 to 36 years (M=29, SD=3.16). Of those, 14 identified as female and 26 as male. 10 participants were assigned to each condition, in which the ratio of males to females, age, and performance on measures of general cognitive ability did not differ from other conditions.

The majority of the participants were familiar with AR content and AR HMDs: 35 of them had experienced AR in various forms at least once, and 31 participants had worn AR HMDs before. In addition, 16 of them had tried AR more than 10 times, whereas 13 of them had used AR HMDs more than 10 times. On the other hand, participants were not heavy game players, nor were they well acquainted to the format of mystery-solving games that involve space, such as Fragments. 30 participants played games for less than five hours a week, and 13 of them did not play games at all.

3.5 Procedures

This study and its procedures were approved by the Korea Advanced Institute of Science and Technology (KAIST) Institutional Review Board (KH2019-51). For the study, participants were first asked to complete a questionnaire regarding their personal information, such as their age, education, and occupation. The questionnaire also asked the number of weekly hours they spent on playing games, their level of prior experience with AR HMDs and AR content, and their familiarity with mystery-solving, narrative-driven games such as Fragments. They were then briefly introduced to the premise and plot of the game before detailed instructions on how to play the game and what their task in the experiment was were given by one of the researchers. Slides containing the same information were shown to the participants during the introduction.

Next, participants were led inside the rooms set in the conditions they were randomly assigned to, and were asked to wear a Microsoft Hololens with an HTC Vive tracker attached to it. After adjusting the headset and familiarizing themselves with the gesture and voice inputs used in the game, the participants were left alone in the room. The starting point of the game for each player was set to be after the room scan process and before the launch of stage 1. The rooms were scanned once before the study for each condition and saved to the game to ensure that every participant playing in the same condition experienced a virtual game space that was created from the same pre-scanned room data. As a result, each clue and virtual character was augmented at the same location (e.g. on top of the table, next to the sofa) in the rooms for each study condition, with only subtle differences in their rotation and coordinate values.

[13]https://www.testmybrain.org/

Upon reaching the end of Stage 1, participants were asked to remove the HoloLens and complete four questionnaires in the following order: (1) the Presence Questionnaire; (2) Narrative Engagement Scale; (3) PSSUQ; and (4) NASA TLX. All questionnaires in this study were administered online through Google Forms. At the end of the questionnaires, the participants were asked to freely comment on how the physical space affected their gameplay. Lastly, participants took the aforementioned Continuous Concentration test to ensure that their cognitive abilities for immersive gameplay were within the general average range. All participants signed consent forms regarding the study procedure and the data they provided. Each study session with a single participant took approximately one hour.

4 Results

In this section, we report the results of measures on presence, narrative engagement, game usability, perceived workload, task completion time, and distance traversed. In addition, we combine key points derived from close observations with participant interviews.

To analyze the quantitative score results of the questionnaires, along with task completion time and distance traversed, we used the two-way ANOVA (α = .05) with room size and the amount of furniture being the two factors, each with two levels (Large or Small; Fully furnished or Scarcely furnished). The Shapiro-Wilk test was used to test the normality of the data distributions and Levenes test to examine the homogeneity of variance. If the distributions were not normal, there were outliers, and the variances were not homogeneous, we applied Aligned Rank Transform (ART) as proposed by Wobbrock et al. [48].

The main results are summarized as follows:

- The sense of presence during the game was stronger for players in the large rooms than those in the small rooms.
- Participants playing in the large rooms felt more engaged with the narrative than those in the small rooms.
- Neither room size nor the amount of furniture had a significant effect on the game's usability.
- Participants who played in the fully furnished rooms felt that the gameplay demanded a higher workload than those who played in the scarcely furnished rooms.
- Both room size and the amount of furniture did not have any significant effect on task completion time and distance traversed.

4.1 Presence

The size of the rooms had a significant main effect on the participants' PQ scores ($F(1,36)$= 6.809, p=.013, η_p^2=.159), but the amount of of furniture did not ($F(1,36)$=1.131, p=.295), as is illustrated in Figure 3(A). Descriptive statistics show that participants who played Fragments in the large room conditions experienced a higher level of presence than those who did in the small room conditions (Large: M=5.51, SD=0.44; Small: M=5.04, SD=0.73). On the other hand, no significant interaction effect was found between the room size and the amount of furniture concerning presence ($F(1,36)$= 0.905, p=.348): The relationships between the size of the rooms and presence were not dependent on how many pieces of furniture there were.

4.2 Narrative Engagement

The degree of narrative engagement to the game among the participants, measured with the Narrative Engagement Scale, was significantly affected by the size of the rooms ($F(1,36)$= 4.257, p=.046, η_p^2=.106), but not by the amount of furniture in the rooms ($F(1,36)$=0.273). Figure 3(B) depicts these results. Players in the

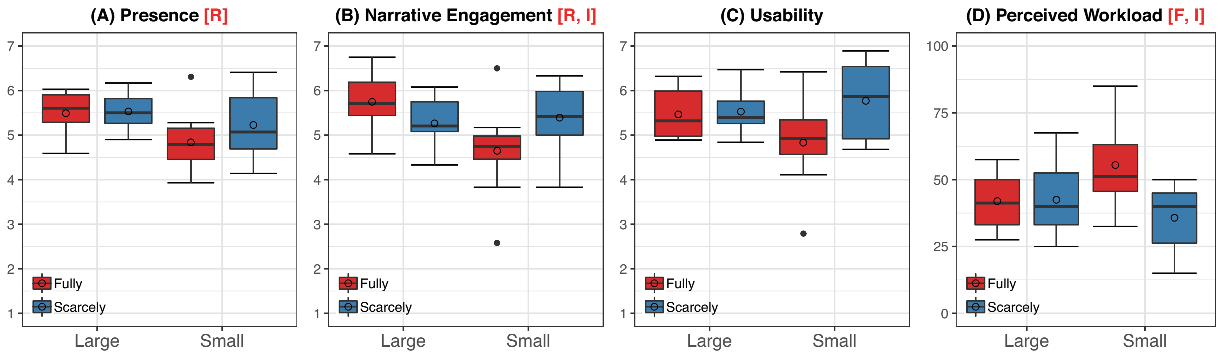


Figure 3: (A) Presence rating results (PQ); (B) Narrative Engagement rating results (Narrative Engagment Scale); (C) Game Usability rating results (PSSUQ); and (D) Perceived Workload rating results (NASA TLX). (o: mean; R and F: significant effect of Room size and the Furniture, respectively; I: significant interaction effect between the two independent variables)

large rooms felt more engrossed in the story of the game than players in the small rooms (Large: *M*=5.51, *SD*=0.68; Small: *M*=5.02, *SD*=0.94).

Furthermore, a significant interaction effect between the room size and the furniture (F(1,36)= 7.351, p=.010, η_p^2=.170) was found regarding this factor. In the Large Room condition, narrative engagement was higher for the participants who occupied the space in a fully furnished state (Fully Furnished: *M*=5.75, *SD*=0.73; Scarcely Furnished: *M*=5.26, *SD*=0.57). For the Small Room condition, however, narrative engagement was higher for those who experienced it with fewer pieces of furniture (Fully Furnished: *M*=4.65, *SD*=1.00; Scarcely Furnished: *M*=5.39, *SD*=0.74).

4.3 Usability

4.3.1 Game Usability

In the case of system usability, neither room size nor the amount of furniture had any significant effect on the participants' PSSUQ scores (room size: F(1,36)=.270, p=.610; furniture: F(1,36)=.225,), as can be seen in Figure 3(C). Additionally, there was no significant interaction effect between the two factors (F(1,36)=.625,p=.440). This shows that the relationship between room size and the usability of the game was free from the influence of the number of furniture items in the space, and that the relationship between furniture and the usability of the game was also not associated with the effect of room size.

4.3.2 Perceived Workload

Figure 3(D) shows that the number of furniture items in the space had a significant main effect on the perceived workload of the participants while they played the game, as reported in NASA TLX scores *(*F(1,36)= 4.872, p=.034, η_p^2=.119,), whereas the room size did not(F(1,36)=0.599). Participants playing in the Fully Furnished rooms felt they had a heavier workload than those who played in the Scarcely Furnished rooms (Fully Furnished: *M*=48.75, *SD*=15.78; Scarcely Furnished: *M*=39.13, *SD*=13.09). Moreover, a significant interaction effect existed between the room size and the amount of furniture for the perceived workload (F(1,36)= 5.391, p=.026, η_p^2=.130). Given that the rooms were fully furnished, the NASA TLX scores of players in the Small Room were higher than that of the players in the Large Room (Large: *M*=42.00, *SD*=10.85; Small: *M*=55.50, *SD*=19.51). On the contrary, participants playing in the large room felt they had a heavier workload than those playing in the small room when the rooms were scarcely furnished (Large: *M*=42.50, *SD*=13.49; Small: *M*=35.75, *SD*=12.42).

4.4 Task Completion Time

Figure 4(A) shows that room size and the amount of furniture did not have any effect on the time it took participants to clear Stage 1 of Fragments (room size: F(1,36)=.275, p=.603; furniture: F(1,36)=.003, p=.959). There was also no significant interaction effect between the two conditions (F(1,36)=.955, p=.335). The relationship between room size and task completion time was not affected by the furniture conditions, and the relationship between the number of furniture and task completion time was independent of the size of the rooms.

4.5 Distance Traversed

Figure 4(B) shows that neither the room size nor the amount of furniture had any significant effect on the total distance participants moved with their feet during the gameplay (room size: F(1,36)=.098, p=.756; furniture: F(1,36)=1.369, p=.250). Additionally, no significant interaction effect between the two independent variables was uncovered in regards to distance traversed (F(1,36)=.001, p=.979). Whether the rooms were fully furnished or scarcely furnished had no effect on the association between room size and the distance participants walked. Conversely, the relationship between the number of furniture and distance traversed was not dependent on whether the rooms participants played the game in were large or small.

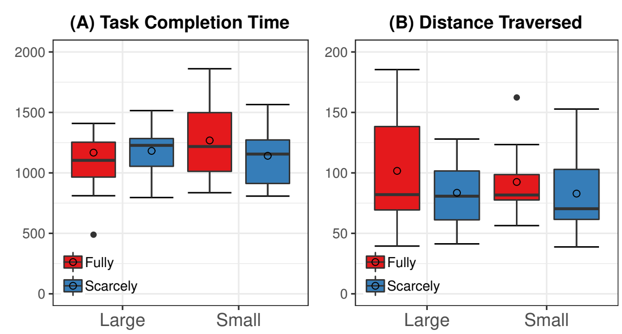


Figure 4: Statistical results for (A) Task completion time (in seconds) and (B) Distance Traversed (in meters) for each study condition

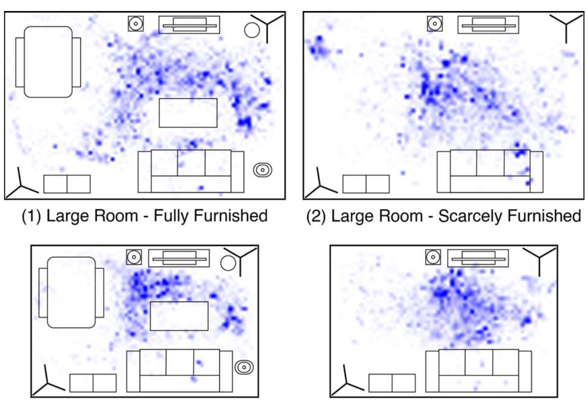
4.6 Observations and Interview Comments

During the gameplay sessions, we monitored and logged all the participants' activities and behaviors to uncover key issues that are consistent with the statistic results reported above. These issues are mainly concerned with the participants' movement, viewing behavior, environment, and device. The observations were also supported by participants' statements given in the post-study interviews.

4.6.1 Movement

To record and analyze patterns in the movement of all participants, we visualized them as normalized heatmaps of timestamps recorded from their position every second for each condition, as is illustrated in Figure 5. The heatmaps indicate two notable commonalities across and within the groups, both of which align with the participants' interviews. Firstly, the participants who played in the large, fully furnished room moved around the space more than those in the same-sized room that was scarcely furnished. This owes to the fact that when there were many pieces of furniture, participants tended to move closer to the clues that were occluded by them. On the contrary, participants in the same-sized, scarcely furnished room were able to examine the evidence across the room without having to move from where they were standing, as the evidence was augmented in a non-occluded area.

Secondly, in line with work by Kim et al. [21], participants in our study mostly treated virtually augmented game objects and characters just as they would treat physical, real-life ones, especially if they were large in size. Consequently, they would not move close to them or pass through spots where they were placed. The empty areas without timestamps or only a slight trace of them on every Rooms and the top right side for the Small Rooms–are all areas where two life-sized virtual characters (the kidnapped child and the kidnapper) were augmented throughout the participants' gameplay. Even when pieces of evidence were found near or in between these characters, most participants stayed at a distance or went around them, just as they did when they found other clues near the dining furniture or the coffee table. This restricted the movement of the players in the Small Rooms more than that of players in the Large Rooms, especially in the fully furnished condition (P26: "*The tables really got in the way when I was trying to investigate*").



(1) Large Room - Fully Furnished (2) Large Room - Scarcely Furnished

(3) Small Room - Fully Furnished (4) Small Room - Scarcely Furnished

Figure 5: The movement of all participants in each condition, represented as normalized heatmaps

4.6.2 Viewing Behavior

In the gameplay videos that were recorded through the HoloLens camera, participants revealed common blind spots in their visual inspections across and within the conditions they were assigned to play in. In general, participants had a tendency to neglect areas closest to their feet when they were searching for new clues (P9: "*It was hard for me to think of looking down because I wasn't aware of that space*"). This was more evident among participants who played in the small room condition, as it took longer for more participants in this category to discover artifacts on the floor, which only appear once the players scan the area with their eyes (P34: "*It was easier to look at large, empty spaces.*"; P30: "*I didn't really pay attention to the floor because the view in front of me was crowded enough, with a lot of information to take in*").

More importantly, the placement of furniture in the rooms influenced the participants' perception of how the augmented game space was constructed. The impression that the game space matched the physical environment very well led to the belief that focusing on spots other than where the furniture was, which were regarded as more natural places for clues to be found, would give them a better chance at progressing further in the game (P19: "*I took it for granted that there won't be any clues where the furniture is, and did not really try to look closely at those spots, even when I did catch a glimpse of something appearing*"). Again, this happened more frequently for participants in the small rooms, where the existence of furniture was more prominently felt than in the large rooms (P40: "*I made an effort not to stay too close to the furniture while I looked around the room from where I was standing to get a wider view of things*").

4.6.3 Physical Environment and Device

Observations and interviews further revealed that participants reacted to conditions other than room size and the amount of furniture during their gameplay, which was centered on elements of the physical environment and inconveniences caused by the HoloLens itself. Many participants remarked that the lighting in the room or the sunlight coming in from the windows impacted them, especially when they were reading information written on the clues (P45: "*It was hard to see the darker parts of the clues shown in the game because the room was brightly lit*"). Few also mentioned noise coming from outside as a disturbance to the voice instructions provided in the game.

On the other hand, the hardware components of the AR interface also had a noticeable impact on the participants' gameplay: Almost all participants were seen to be holding the device with one hand as they progressed further in the game (P33: "*The headset was heavy and became loose as I moved around*"). The display's limited Field of View (FoV) was also mentioned often in the interviews as a factor that impeded their activities in the game (P28: "*It was uncomfortable to have such a narrow view when there were many things to look for*").

5 Discussion

5.1 Analysis on the Study Results

In our results, measures for the sense of presence were rated significantly higher for participants who played Fragments in the two large room conditions. This confirms our first hypothesis (H1), in which we postulated that large spaces were more suited to foster a high sense of presence. Observations showed that participants playing in the large rooms were able to move around more easily and freely than those in the Small Rooms. In accordance with previous related studies, they felt a heightened sense of being in the game by being more exposed to their natural body movements [3, 43]. That there was no significant difference in the distance traversed and time spent on the game between groups implies that awareness of one's own physical activity during the game may be more relevant to the sense of presence than the actual activity itself.

In addition, more participants that played the game in the large rooms stated that they were able to perceive and appreciate how the virtual game space was well adapted to the features of the physical space than the players in the small rooms had. They could not feel any particular discordance in their experience, which helped them erase the existence of the medium and focus more on being in the experience. This happened regardless of the amount of furniture that was placed in the rooms, as the large rooms provided enough space for them conduct themselves without feeling that the furniture in the real world was standing in the way of their task in the virtual game world.

We found that the amount of furniture in the rooms was not significantly associated with the sense of presence, which leads us to reject the second hypothesis (H2) that spaces filled with furniture will have a positive impact on presence. Contrary to our belief that more visual signs representing the connection between the real world and the virtual world will help increase the degree of presence [3], this aspect could not be attributed. This seems to be on account of the fact that placing many pieces of furniture did not necessarily entail a higher level of spatial adaptiveness in the game. Rather, it created a complicated scene where both the physical objects and the virtually augmented clues were presented in parallel, making the discrepancy between them more apparent.

In addition, whether the gaming environment featured many pieces of furniture or not did not have any significant impact on the participants' narrative engagement. Therefore, we also reject our third hypothesis (H3) that more furniture will lower the level of narrative engagement during the game. What was actually shown to affect how interested and involved the participants were in the story of the game was the size of the room the narrative space was mapped onto: Participants in the large rooms scored higher on the Narrative Engagement Scale that those in the small rooms. We speculate that this is on account of the fact that characteristics of narrative engagement overlap with presence, as was evinced in our related work, and that narrative engagement was high for similar reasons that presence was in the large rooms.

Moreover, it was found that the large, fully furnished room was a better environment for narrative engagement than a scarcely furnished room of the same size. This contradicts a previous study stating that increasing the visibility of the real space leads to lower engagement [35]. In the case of small rooms, however, the number of furniture had a reverse impact on narrative engagement: Narrative engagement was indeed higher in the scarcely furnished condition. Through our observations and interviews, we were able to learn that moving around in a sufficiently large space where the augmented clues were sometimes hidden or made hard to find by the real furniture deepened the participants' interest in the story. On the other hand, the same effect was achieved when there was less amount of furniture in the small room because the spatially adapted game space provided a similar level of difficulty in that condition; when the same amount of furniture was in the small room, the task of finding clues and getting engaged in the story became challenging rather than enjoyable.

Regarding usability, which was measured with two different scales (PSSUQ for game usability and NASA TLX for perceived workload), only one of them (NASA TLX) was found to be significantly affected by the amount of furniture, with an interaction effect regarding room size: The perceived workload was higher for participants who played in the fully furnished rooms than in the scarcely furnished ones. Therefore, our fourth hypothesis (H4), which stated that usability will be low in small rooms with many objects in them, is accepted in terms of perceived workload but rejected for game usability. Our result is in line with previous work that found providing enough space for the user to view and control virtual objects is a usability requirement for AR applications [29]. When the space was small and cluttered, participants had a hard time looking down at the area around their feet, which led them to miss clues needed to accomplish the task in the game. Furthermore, the fact that participants in general perceived life-size virtual characters as if they were real and moved around them, which is in accordance with avoidance behavior in AR environments as observed by Kim et al. [21], seems to have added to the workload in the small, fully furnished room.

One other interesting finding to note is the fact that usability as measured by the PSSUQ were not significantly affected either by room size or the amount of furniture. In the post-study interviews, we found that this aspect of usability was closely related to factors that were not influenced by whether the room was large or small, and whether it had much furniture in it or not. Many participants stated that they were quite aware of the HoloLens itself, as it was quite heavy to endure without holding it with their hands for additional support during there gameplay, which lasted for as long as over 20 minutes. The limited field of view and resolution were also often mentioned as the reasons that made it hard for them to perform their task. We infer that the usability of the content participants experienced was interchangeably thought of as the usability of the display device, and that this may have led to the non-association between room size and the number of furniture to usability in the statistical results.

5.2 Design Implications

Based on our analysis, we derived design implications for narrative-driven, space-adaptive indoor AR HMD applications in regards to how the features of physical spaces should be considered in mapping and augmenting virtual elements.

Controlling the Adaptiveness: The results of our study indicate that adapting the augmented game space to the physical indoor space is an effective strategy to increase the sense of presence and narrative engagement of the player. A clear visual representation of how the two co-existing spaces in the game world blend into one another creates a realistic illusion that they are ultimately one and the same as the backdrop of a story the player is a part of. However, it is better to partially constrain the adaptiveness when the conditions of the physical space have a degrading effect on the player's experience. As an example, our findings imply that in situations where the physical indoor space is large and empty, managing the size of the augmented space to be smaller than the physical space can be one way to reduce the perceived task load.

Leveraging Virtuality for Reality: One other way of complementing the shortcomings of a physical indoor space to foster a quality narrative experience in AR through HMDs is to make use of virtual objects augmented within that space. This is supported by our observation that players generally perceive them as components of their real surroundings and interact with them as such. When the physical indoor space has few pieces of furniture, which negatively impacts narrative engagement, virtual objects can be used as substitutes for real-life items to create an environment that improves this aspect of experience in the game. In addition, we recommend that virtual objects be augmented at eye level when the physical indoor space is filled with furniture in order to alleviate the player's workload. Since our study has found that having to look down at cluttered floors challenges the player both physically and mentally, adjusting the positions of the virtual augmented objects so that there is less strain on the user can be a remedy to the problem in real space.

On a side note, room size and the amount of furniture are not the only factors that define the spatial environment of indoor AR applications experienced through HMDs; the usability of such content can be affected more by lighting conditions, overall noise level, and device quality. Therefore, these aspects should be accounted for in the presentation and duration of the experiences that the content provide before the conditions of augmented game space can best be adapted to those of the physical indoor space. Such measures will help to reinforce the positive effects of adaptive spatial mapping and augmentation on user experience.

5.3 Limitations

Our findings provide meaningful insight into how players perceive, engage in, and interact with space-adaptive, narrative-driven content for indoor AR environments in different types of spaces through HMDs. However, there are some issues that were not sufficiently addressed in the current study. The first limitation concerns the size of our data at 10 participants per study condition. While this number is sufficient to be statistically valid [40], a larger sample size will provide more ample sources for both quantitative and qualitative analysis.

Secondly, we need to test our conditions with a wider variety of applications designed to adapt their virtual elements to the physical realm. Fragments exemplify the core characteristics and values that this line of content aims for. Nevertheless, differences in the way the narrative is structured or how the virtual elements are mapped and utilized in other similar content may yield different results regarding the influence of room size and furniture on player experience.

Thirdly, the criteria by which we determined the specifics of our conditions should be better defined and justified. The measurements for the large and small rooms, along with the decision on how many pieces of furniture there should be in the fully furnished and scarcely furnished conditions, were grounded in minimum figures that the game required for it to scan the physical space and launch the experience. As we aimed for a relative comparison, they were ultimately based on subjective judgments on how large and small, full and scarce could be physically presented and perceived.

Lastly, player experience was measured in only two conditions for each independent variable. The results may have shown other interesting interactions effects or notable findings in the observations had there been more variations in room size and the amount of furniture. Examining how players experience the game differs along a broader range of conditions regarding the size and density of indoor spaces will provide a deeper understanding of how they change the game space and the situations players are faced with.

6 Conclusion and Future Work

In this paper, we investigated the effect of room size and furniture on the players' sense of presence, narrative engagement, and usability during their experience of Fragments, a space-adaptive indoor AR game for the Hololens. In order to test the hypotheses we established, we conducted a between-subject user study that assigned participants to one of four spatial conditions and measured related factors of player experience. The results showed that playing in large rooms is beneficial to enjoy a high level of presence and narrative engagement during the game. On the other hand, participants who played the game in the fully furnished rooms felt they were faced with a higher workload than those in the scarcely furnished rooms.

Analyzing the statistic results with observations and logs of the participant's activities during the game, we conclude that the space-adaptive features of narrative-based applications for indoor AR environments as experienced through HMDs are not always effective. Therefore, they call for the need to be used in parallel with user-oriented design constraints. We suggest: (1) controlling the adaptiveness in certain spatial settings that disrupt the player experience, (2) utilizing virtual augmented objects to overcome the shortcomings in the physical space, and (3) considering other aspects in the gaming environment to aid the effect of spatial mapping as three possible methods.

Our future work will involve further explorations on how features of physical space impact a wider range of AR narrative content designed for the same type of device, such as multi-player role-playing games and interactive cinema. In doing so, we will also improve upon our current study design with clearer standards on how indoor spaces can be classified. Based on the categories we establish, we plan to expand the number and range of spatial conditions to be tested. Furthermore, we would also like to apply our approach in configuring the relationship between space and narrative experience in AR to applications aimed for outdoor spaces, where the spatial traits differ vastly from that of indoor environments.

Acknowledgments

This research was supported by the Ministry of Culture, Sports and Tourism (MCST) and Korea Creative Content Agency (KOCCA) in the Culture Technology(CT) Research & Development Program 2019. This research was supported by the Next-Generation Information Computing Development Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Science, ICT (NRF-2017M3C4A7066316). This work was partly supported by the Institute of Information & communications Technology Planning & Evaluation (IITP) grant funded by the Korean government (MSIT) (No.2019-0-01270, Wise AR UI/UX Platform Development for Smartglasses) and the Korea Evaluation Institute of Industrial Technology(KEIT) grant funded by the Korean government(MOTIE) (No.2019-0-01270, Wise AR UI/UX Platform Development for Smartglasses).

References

[1] M. Billinghurst, H. Kato, and I. Poupyrev. The magicbook-moving seamlessly between reality and virtuality. *IEEE Computer Graphics and applications*, 21(3):6–8, 2001.

[2] S. W. Bindman, L. M. Castaneda, M. Scanlon, and A. Cechony. Am i a bunny?: The impact of high and low immersion platforms and viewers' perceptions of role on presence, narrative engagement, and empathy during an animated 360 video. In *Proceedings of the 2018 CHI conference on human factors in computing systems*, p. 457. ACM, 2018.

[3] F. Biocca. Can we resolve the book, the physical reality, and the dream state problems? from the two-pole to a three-pole model of shifts in presence. In *EU Future and Emerging Technologies, Presence Initiative Meeting*. Citeseer, 2003.

[4] S. Buchholz and M. Jahn. Space in narrative, 2005.

[5] R. Busselle and H. Bilandzic. Measuring narrative engagement. *Media Psychology*, 12(4):321–347, 2009.

[6] D. Carr, G. Schott, A. Burn, and D. Buckingham. Doing game studies: A multi-method approach to the study of textuality, interactivity and narrative space. *Media International Australia incorporating Culture and Policy*, 110(1):19–30, 2004.

[7] A. Colley, J. Thebault-Spieker, A. Y. Lin, D. Degraen, B. Fischman, J. Häkkilä, K. Kuehl, V. Nisi, N. J. Nunes, N. Wenig, et al. The geography of pokémon go: beneficial and problematic effects on places and movement. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, pp. 1179–1192. ACM, 2017.

[8] J. E. Cross. What is sense of place? Colorado State University. Libraries, 2001.

[9] S. Dow, M. Mehta, E. Harmon, B. MacIntyre, and M. Mateas. Presence and engagement in an interactive drama. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pp. 1475–1484. ACM, 2007.

[10] P. Fuchs, G. Moreau, and P. Guitton. *Virtual reality: concepts and technologies*. CRC Press, 2011.

[11] R. Galantay, J. Torpus, and M. Engeli. Living-room: interactive, space-oriented augmented reality. In *Proceedings of the 12th annual ACM international conference on Multimedia*, pp. 64–71. ACM, 2004.

[12] Y. Georgiou and E. A. Kyza. The development and validation of the ari questionnaire: An instrument for measuring immersion in location-based augmented reality settings. *International Journal of Human-Computer Studies*, 98:24–37, 2017.

[13] L. Germine, K. Nakayama, B. C. Duchaine, C. F. Chabris, G. Chatterjee, and J. B. Wilmer. Is the web as good as the lab? comparable performance from web and lab in cognitive/perceptual experiments. *Psychonomic bulletin & review*, 19(5):847–857, 2012.

[14] B. Guo, R. Fujimura, D. Zhang, and M. Imai. Design-in-play: improving the variability of indoor pervasive games. *Multimedia Tools and Applications*, 59(1):259–277, 2012.

[15] R. Hammady and M. Ma. Designing spatial ui as a solution of the narrow fov of microsoft hololens: Prototype of virtual museum guide. In *Augmented Reality and Virtual Reality*, pp. 217–231. Springer, 2019.

[16] S. G. Hart. NASA-task load index (NASA-TLX); 20 years later. In *Proceedings of the human factors and ergonomics society annual meet-*

ing, vol. 50, pp. 904–908. Sage publications Sage CA: Los Angeles, CA, 2006.
[17] S. G. Hart and L. E. Staveland. Development of NASA-TLX (task load index): Results of empirical and theoretical research. In *Advances in psychology*, vol. 52, pp. 139–183. Elsevier, 1988.
[18] S. Hones. Literary geography: setting and narrative space. *Social & Cultural Geography*, 12(7):685–699, 2011.
[19] M. T. Kelso, P. Weyhrauch, and J. Bates. Dramatic presence. *PRESENCE: Teleoperators & Virtual Environments*, 2(1):1–15, 1993.
[20] K. Kim, M. Billinghurst, G. Bruder, H. B.-L. Duh, and G. F. Welch. Revisiting trends in augmented reality research: A review of the 2nd decade of ismar (2008–2017). *IEEE transactions on visualization and computer graphics*, 24(11):2947–2962, 2018.
[21] K. Kim, D. Maloney, G. Bruder, J. N. Bailenson, and G. F. Welch. The effects of virtual human's spatial and behavioral coherence with physical objects on social presence in ar. *Computer Animation and Virtual Worlds*, 28(3-4):e1771, 2017.
[22] S. M. Ko, W. S. Chang, and Y. G. Ji. Usability principles for augmented reality applications in a smartphone environment. *International Journal of Human-Computer Interaction*, 29(8):501–515, 2013.
[23] J. R. Lewis. Psychometric evaluation of the pssuq using data from five years of usability studies. *International Journal of Human-Computer Interaction*, 14(3-4):463488, 2002.
[24] M. Lombard and T. Ditton. At the heart of it all: The concept of presence. *Journal of computer-mediated communication*, 3(2):JCMC321, 1997.
[25] J. Y. Ma and J. S. Choi. The virtuality and reality of augmented reality. *Journal of multimedia*, 2(1):32–37, 2007.
[26] B. MacIntyre, J. D. Bolter, E. Moreno, and B. Hannigan. Augmented reality as a new media experience. In *Proceedings IEEE and ACM International Symposium on Augmented Reality*, pp. 197–206. IEEE, 2001.
[27] W. E. Mackay. Augmented reality: linking real and virtual worlds: a new paradigm for interacting with computers. In *Proceedings of the working conference on Advanced visual interfaces*, pp. 13–21. ACM, 1998.
[28] L. Manovich. The poetics of augmented space. *Visual communication*, 5(2):219–240, 2006.
[29] M. McGill, D. Boland, R. Murray-Smith, and S. Brewster. A dose of reality: Overcoming usability challenges in vr head-mounted displays. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, pp. 2143–2152. ACM, 2015.
[30] N. McNamara and J. Kirakowski. Defining usability: quality of use or quality of experience? In *IPCC 2005. Proceedings. International Professional Communication Conference, 2005.*, pp. 200–204. IEEE, 2005.
[31] C. H. Miller. *Digital storytelling: A creator's guide to interactive entertainment*. Focal Press, 2014.
[32] C. D. Murray, J. Fox, and S. Pettifer. Absorption, dissociation, locus of control and presence in virtual reality. *Computers in Human Behavior*, 23(3):1347–1354, 2007.
[33] K. Nagata, S. Masuko, and J. Hoshino. Construction of mixed reality story environment based on real space shape. In *International Conference on Entertainment Computing*, pp. 260–265. Springer, 2018.
[34] G. Ng, J. G. Shin, A. Plopski, C. Sandor, and D. Saakes. Situated game level editing in augmented reality. In *Tangible and Embedded Interaction*, pp. 409–418, 2018.
[35] A. I. Nordin, P. A. Cairns, M. Hudson, A. Alonso, and E. H. C. Gámez. The effect of surroundings on gaming experience. In *FDG*. Citeseer, 2014.
[36] J. V. Pavlik and F. Bridges. The emergence of augmented reality (ar) as a storytelling medium in journalism. *Journalism & Communication Monographs*, 15(1):4–59, 2013.
[37] G. Prince. *A dictionary of narratology*. U of Nebraska Press, 2003.
[38] A. Pyae and L. E. Potter. A player engagement model for an augmented reality game: A case of pokémon go. In *Proceedings of the 28th Australian Conference on Computer-Human Interaction*, pp. 11–15. ACM, 2016.
[39] E. Relph. *Place and placelessness*, vol. 1. Pion, 1976.
[40] J. Sauro and J. R. Lewis. *Quantifying the user experience: Practical statistics for user research*. Morgan Kaufmann, 2016.
[41] R. Shilkrot, N. Montfort, and P. Maes. narratives of augmented worlds. In *2014 IEEE International Symposium on Mixed and Augmented Reality-Media, Art, Social Science, Humanities and Design (ISMAR-MASH'D)*, pp. 35–42. IEEE, 2014.
[42] A. Studios. Fragments by asobo studios, 2019.
[43] A. Tang, F. Biocca, and L. Lim. Comparing differences in presence during social interaction in augmented reality versus virtual reality environments: An exploratory study. *Proceedings of PRESENCE*, pp. 204–208, 2004.
[44] J. Thoss, A. Ensslin, and D. Ciccoricco. Narrative media: The impossibilities of digital storytelling. *Poetics Today*, 39(3):623–643, 2018.
[45] W. L. Tong and M. C. C. Tan. Vision and virtuality: The construction of narrative space in film and computer games. *ScreenPlay: cinema/videogames/interfaces*, pp. 98–109, 2002.
[46] M. Weiser. Creating the invisible interface:(invited talk). In *Proceedings of the 7th annual ACM symposium on User interface software and technology*, p. 1. ACM, 1994.
[47] B. G. Witmer, C. J. Jerome, and M. J. Singer. The factor structure of the presence questionnaire. *Presence: Teleoperators & Virtual Environments*, 14(3):298–312, 2005.
[48] J. O. Wobbrock, L. Findlater, D. Gergle, and J. J. Higgins. The aligned rank transform for nonparametric factorial analyses using only anova procedures. In *Proceedings of the SIGCHI conference on human factors in computing systems*, pp. 143–146. ACM, 2011.