STORY CREATAR: A SPATIAL ANALYSIS TOOL FOR SPACE-ADAPTIVE STORY CONTENT PLACEMENT

by

Abbey Singh

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Abstract

Immersive locative augmented reality (AR) provides rich storytelling possibilities. When authors place content in a locative AR narrative, they must consider the relationships between the environment, the player's perspective, and story events. This becomes challenging and time-consuming when designing for many or unknown locations. We present Story CreatAR, a locative authoring tool that uses spatial analysis techniques to facilitate multi-site deployment. Story CreatAR was iteratively designed to help authors consider, test, and adjust spatial relationships in their story. We evaluated Story CreatAR in several ways: authors used Story CreatAR with a graph representation of their story and with a script, and developers did the same. Through a thematic analysis of user comments and behaviour we find authors had difficulty understanding spatial analysis concepts and thinking abstractly about placement across multiple sites. However, Story CreatAR encouraged authors to consider how environments impact their stories, and authors desired additional spatial analysis features.

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Chapter 1

Introduction

Headworn augmented reality (AR) and virtual reality (VR) are emerging as immersive, exciting mediums for locative experiences. VR immerses the user in a 360° virtual environment, whereas AR renders virtual objects in the real world. VR designers can correlate the real world with the virtual world when designing a locative VR experience (e.g., VR escape rooms that take place in real rooms). However, for locative experiences AR is more practical as viewers are more aware of the context of their surroundings, making AR more suitable for public and uncontrolled spaces. These AR experiences can be delivered through handheld devices or head-mounted displays (HMDs) such as the HoloLens 2 [91] and Magic Leap One [5].

While the mediums of immersive AR and VR are different, they both make use of the physical environment, both support embodied forms of interaction like head movements, and the head-worn devices have similar form factors. Heizenrader [16] identifies three types of virtual reality: non-immersive VR (e.g., video games on a computer screen), semi-immersive VR (uses 3D graphics), and immersive VR (e.g., uses a HMD). In this thesis when we state VR and AR, we refer to immersive VR and immersive AR. Handheld devices can be more cost-effective than HMDs, but they lack the immersive qualities of headset-driven 360 degree graphics, video, and motion tracking. Tethered headsets allow for a high quality experience, but do not easily permit mobile experiences as they need to be attached to a powerful computer. Standalone headsets sacrifice some processing power to permit the creation of truly "walkable" immersive experiences, and these are the type of headset targeted by the work in this thesis. AR HMDs provide an opportunity for rich integration of virtual content with the physical world. We also use VR HMDs to test mobile immersive experiences, as such headsets are more readily accessible and can be used in almost any space. Due to COVID-19, most testing of our immersive story experiences was done in VR, with a final deployment in AR.

Locative media is media that contains content about the location it is experienced in. We generally have two types of locative experiences: a site-agnostic experience or a site-specific experience. A site-agnostic experience is one that is created independent of the location it is experienced at (e.g., hide and seek can be played in any location). A site-specific experience is one that is designed for a specific location (e.g., a walkable tour through a Nova Scotia museum). Locative media is difficult to design effectively as the location adds another layer of complexity [73]. When a story becomes complex or the target physical environment is large, designers need to consider complex relationships between the viewer's perspective, position, and orientation with respect to the story content. Therefore, placing story content in appropriate locations manually becomes time-consuming. Locative media becomes even more challenging when we want to extend the experience to multiple locations, or even unknown locations, as this does not readily permit manual placement of story elements.

Some research applications exist that adapt an experience to any environment [41, 55]. However, these approaches often follow a greedy algorithm where they dynamically match virtual content to new spatial configurations during the experience: thus they do not consider the entire floorplan *a priori*; these approaches for greedily placing story content do not allow for the story to make full use of the environment until it has been completely explored (e.g., if avatar leads the viewer to a room not yet explored), but by then existing content will have already been dynamically placed. In addition, the order in which a viewer explores the environment would also change how the virtual content is presented. Locative media tools have been explored in research, but are often designed for a particular use-case and is experienced at a single location [25, 56, 84]. This has several drawbacks for this area of research: these systems quickly become unused, the locative media examples are often designed by developers as opposed to authors, and there remain unaddressed challenges for designing locative media content more broadly. Important questions regarding how to appropriately design locative media creation tools remain, including:

- How can the findings for a particular locative media project be used to design a more generalized tool?
- How can locative media developed for a specific location be extended to a new location?

- What new challenges need to be addressed for an authoring tool to support *site-adaptive* locative media?

In this thesis I explore these questions through the design and evaluation of Story CreatAR, which is the first authoring tool to utilize spatial analysis techniques *isovist and convex analysis* and socio-spatial theory *F-formationss and proxemics* to facilitate site-adaptive, walkable, immersive AR experiences. Story CreatAR offers realistic human characters and animations, spatialized audio, and 3D objects sourced by the author. Authors can organize their content into groups using labels to help organize complex content and to help apply placement rules to multiple objects. High-level placement rules are used to hide the complexities of the lower-level space syntax characteristics and can be used for placing story content. Authors can add floorplans of a new location or use the sample floorplans provided by the tool. Authors can view multiple versions of the placement on a given floorplan or on different floorplans. Authors are able to preview the story in a 3D environment, where they are able to make modifications to the placements and events. Then, they can deploy to VR (Oculus Quest) for testing or AR (HoloLens 2) for on-site deployment.

Authors are able to use Story CreatAR to place story content through an association with spatial rules, irrespective of the target deployment environment. Story CreatAR uses spatial analysis techniques that adapt the story to a location *before* deployment to that location. The spatial analysis techniques additionally consider the entire floorplan, potentially providing an *optimal* position for story content, rather than a *greedy* position. Due to the use of the socio-spatial mechanisms, we can also avoid the issue of story events occurring in locations that the viewer has yet to explore.

We arrived at the design of Story CreatAR in three ways. First, we conducted a range of design-oriented research activities (e.g., brainstorming mappings between narrative elements and spatial relations, conducting user interviews with locative media practitioners) to uncover key features our tool could employ. We found that authors should themselves be able to associate, test, and modify spatial rules for their story. Second, we followed an iterative user-centered design process (i.e., creating scenario-driven storyboards, conducting walkthroughs using low-fidelity prototypes) where we worked closely with authors to find Story CreatAR features that would be useful for their stories. These features were then tackled incrementally by a development team in a series of sprints, and the functionality was verified by the same authors. I played an integral role in the development as I created Story CreatAR's author facing interface and integrated key components of Story CreatAR exposed by other students (e.g., spatial analysis functionality and event configuration).

Resulting from our design and development process, Story CreatAR provides authors with an interface that allows them to specify:

- *placement rules* to associate virtual story content with spatial characteristics based on space syntax and room constraints,
- *traversal rules* to associate realistic avatars with movement qualities (target position, traversal path, urgency), and
- *formation rules* to arrange avatars and objects based on F-formationss, proxemics, and room constraints.

Story CreatAR was evaluated with three Dalhousie University film and media studies students as authors, each with their own story. We held weekly sessions with the authors during the conception of their story script where we discussed spatial analysis techniques we may use in Story CreatAR, relevant locative media literature, and demonstrated Story CreatAR features. Authors translated the story script to a graph representation, used Story CreatAR to implement different sections of their story (one section using only the graph and another using only the script), and then a developer implemented different sections of the author's story (one section using only the graph and another using only the script). We were interested in how effectively authors understood and used spatial analysis techniques, and how the translation to Story CreatAR differs using the script compared to the graph. A graph may better illustrate nonlinear narratives, player interactions, the higher-level story structure, and spatial relationships [67, 95], which may aid the author with translating their story to Story CreatAR. We explore how an author and developer each use Story CreatAR to see the differences and similarities in how they use the interface. Both users use the script and graph story representation in isolation, so we can examine the pros and cons of using each story representation. However, we expect a user of our tool may use a combination of story representations (e.g., both graph and script).

In the evaluation, we explored several questions.

- In the graph, script, and while using Story CreatAR, how did authors organize their stories (e.g., the story could be organized by rooms or scenes)?
- What spatial rules did authors define in their graph that they were unable to define in the script? What spatial rules did authors define in their script or graph that they were unable to define in Story CreatAR?
- What information (continuity issues, spatial placement, etc.) is missing from the author's story representation that is necessary for an immersive AR storytelling experience?
- Did authors understand and use the spatial rules provided by Story CreatAR effectively? Which spatial rules did they use, how many did they use, and how easily were they able to achieve their desired outcome?
- How does implementing a section of the author's story in Story CreatAR differ for an author and a developer? How does it differ between using the graph representation and the story representation?

We found that our authors produced vastly different story graph representations. Although, all authors specified placement rules within their story graph and script, authors misunderstood spatial analysis techniques used in Story CreatAR. While authors were interested in creating a site-adaptive narrative, authors had difficulty thinking of placement abstractly. Moreover, authors desired additional placement rules that are currently unsupported by Story CreatAR. Despite these challenges, authors were still able to apply spatial concepts in their story representations and while using Story CreatAR.

The thesis is organized as follows. The first chapter, *Background* provides information on spatial analysis and narrative theory, and locative AR properties and examples. *Preliminary work* details prior work I conducted during my undergraduate directed studies. *Story CreatAR* presents the system features and workflow. The subsequent chapters, *Evaluation of Authors using Story CreatAR*, *Results of Authors using Story CreatAR* and *Discussion of Authors using Story CreatAR* introduce and discuss results on our evaluation of Story CreatAR. I worked closely with other students during the creation of Story CreatAR and the evaluation. During the evaluation I worked closely with the authors during the different phases. The *Discussion* chapter details future directions for Story CreatAR, as well as current and future work. Lastly, the appendices provide more details on the Story CreatAR interface, design artifacts, and future/current studies.

Chapter 2

Background

2.1 Introduction

In this chapter, I describe related literature. I begin by discussing locative media tools, examples, guidelines, and the relevance of narrative theory to locative media. I present spatial analysis techniques used in Story CreatAR (space syntax, room-based analysis, proxemics, and F-formationss). I also discuss tools for creating spatially adaptive AR/VR experiences. I present spatial considerations for immersive AR/VR experiences. Then, I discuss related AR/VR authoring systems to validate our system, Story CreatAR. Following, I discuss the impact of the medium (AR/VR) on the viewer. Lastly, I conclude with different ways to represent narratives, which motivates our evaluation of Story CreatAR where we compare how two different narrative representations facilitate the implementation of an author's story in Story CreatAR.

2.2 Locative Media

We frame the design of our tool on findings from locative media research projects, tools, and literature. In one example of a research-driven project the Mobile Digital Commons Network (MDCN) [84] created two locative media projects: *Urban Archaeology: Sampling the Park* and *The Haunting* using audio, imagery, and GPS sensors from the Mobile Bristol Toolkit. The Mobile Bristol Toolkit is a collection of software used by researchers to map heritage sites to their communities. Authors were able to add media files (e.g., images, sounds, etc.) through a drag and drop interface and use a map to specify the physical location of the content. A takeaway message from this project is that a user cannot simply think of the relationships between objects and people, but also about the space and place these relationships are encountered. This is a critical challenge for locative media content creators. This raises the debate between "place" and "space" [49]. *Place* refers to the human use of the space, which impacts and shapes experiences located within the *space*. Story CreatAR authors must consider both the social interactions that will take place during their experience and the physical layout of the building as both will affect their story presentation.

Another example designed for a particular use case is *Train Constellations* [56], an audio-based AR experience that involves both implicit interactions (i.e., sensor-based) and explicit interactions (i.e., direct user interaction) in combination with physical artifacts. They examined how audio affects the AR experience and found mixed responses: audio created a social experience, but participants required additional guidance (e.g., an audible cue for an event has started). Audio rather than text is a principal form of content offered by Story CreatAR.

Ardito et al. [25] present a mobile AR location-based historical learning experience at one location. They create this experience following "Learner-Centered" methodology, where the creators involve field experts throughout the system development and evaluate its usability with real users. They bring together locative and game-like aspects to encourage youth to learn about history. Pilot studies indicated that youth experienced learning and enjoyed this experience. Story CreatAR follows a similar methodology by involving authors in the design process of the tool.

However, such locative media tools and experiences face significant challenges regarding the design of the experience for different users (e.g., unpredictability of a user's location both during and across experiences and players having different physical abilities) and device capabilities (e.g., unavailable GPS signal, low processing power, limited storage, and small screen size) [73]. Jacob and Coelho [73] demonstrate a solution framework to address some of these locative game issues: using cached location data when a GPS signal is unavailable and determining the user's pace to find how difficult the game is and adjust accordingly. This framework was tested with a location-based game they created, *Geo Wars* and preliminary feedback was positive. Although, Jacob and Coelho's framework supports mobile games, it can be generalized to suggestions for immersive AR storytelling: in AR a user may lose tracking so positions of virtual content could still be maintained based on their last known position without having reference to the physical space. Accounting for the player's physical abilities is not an issue in VR or other mediums that use a virtual locomotion technique to control the player's pace. Both movements, using a mobile device or an AR HMD require additional planning for content creators to allow the viewer to control the pace (e.g., viewer interaction controls the progression of story events). Therefore, Story CreatAR provides events that are controlled by viewer movement and orientation.

Due to the limited applicability of previous systems [67], StoryPlaces [67] was designed as a generic web-based authoring system for creating and reading locative narratives. StoryPlaces uses *sculptural hypertext* to represent their narratives, where every node in the graph is linked by default, then those links are sculpted away by guards (conditions). These conditions can be logical, locative, and time-based constraints. For example, Bob is eating (logical) and at school (locative) between 1 pm and 2 pm (time). StoryPlaces demonstrates its generalizability as it was used to create 21 stories of various types (e.g., linear narratives, short stories) with authors and readers from various academic and professional fields. As StoryPlaces is contemporary research, we were unaware of it when Story CreatAR was being designed and implemented. I will reflect on key design differences and their potential implications in the Discussion chapter.

2.2.1 Location-Based Games

Unlike locative storytelling, locative games have a larger consumer reach and the availability of some generalized properties such as the type of content created [98]. As there exist several overlapping properties between various genres of games and narratives (e.g., events, objects, locations, and characters [21]), some insights for locative games may be extended to locative narratives. Therefore, these insights may inform authors using Story CreatAR.

A popular location-based mobile AR game is *Pokémon Go* [99]. Pokémon Go uses the user's real world movements to dynamically adapt virtual game content to the user's physical location. Pyae et al. [109] and Sobel et al. [124] examine the experience of users in Pokémon Go and found that the game encouraged physical activity, outdoor exposure, and social activity in a fun way. Locative storytelling may provide similar benefits as the locative aspect may encourage users to move around, the medium may facilitate an outdoor experience, and multiplayer functionality can create enjoyable social experiences. For experiences created through Story CreatAR,

Type of Play	**Fixed**	Specific locations or a specific time
	Continual	Any time and anywhere
Type of Content	**Light**	Easy to make and do
	Elaborate	More difficult to do and make
	Complex	Most challenging to do and make
Player Interactions	**Synchronous**	Interact at the same time
	Asynchronous	Interact at different times
Who creates the content	**Game Admin.**	Manually develop content for a specific location
	User-generated	Players create content themselves
	Automatic	Can be done through spatial analysis, use of landmarks, etc.

Table 2.1: Different properties of location-based games

we provide the ability for authors to incorporate game-like elements.

Geocaching is another prominent location-based mobile activity, where a geocache is hidden in the real-world and the mobile device directs the user to a GPS location and provides a description of the geocache and supplementary hints. Geocaching supports user-generated content, which allows users to create locative media [98]. The content can differ in complexity and Geocaching has strict rules for placing, retrieving, and manipulating content. Content can be monitored by players easily though online activities and non-players can also be monitored (e.g., reporting that someone stole the cache). Additionally, players can easily replace other player's content to keep it up-to-date. Neustaedter and Tang [98] look into how game content can be created to overcome the challenge of scaling locative media by investigating Geocaching. They find Geocaching is able to scale by having user generated content and user maintenance of that content. Story CreatAR also provides scalability, but instead of scaling the content, the location is being scaled.

Understanding existing properties, guidelines, and considerations for locative media can help inform the design of a locative authoring tool and what features such a tool should offer. Neustaedter and Tang [98] use Geocaching to find certain properties common to location based media. The different properties are *type of play*, *type of content*, *player interactions*, and *who creates the content*. Table 2.1 provides definitions for each type of each property. Story CreatAR permits all types of play and content. Story CreatAR permits fixed play for site-specific experiences and continual play for site-agnostic experiences. Providing simple content allows new users to quickly create experiences, which as in the case of Geocaching allows for a variety of content to be generated at many locations. Providing more elaborate or complex content allows users to have increased enjoyment from the game, which may keep the user to play the game long term. Authors can generate content (their story) and an association of spatial mappings for automatic generation of game content in Story CreatAR. Game administrators may make adjustments to the content based on the semantics of the floorplan (e.g., moving story content outside a female washroom). As monitoring and adjusting story content may become time-consuming if only done by game administrators, we may consider including a more obvious way for authors to share their narratives with others in Story CreatAR.

Some location-based games used for research include Gaea [40] (encouraging virtual trash removal through a mobile device), Martians from Outer Space [71] (players use a public display to eliminate martians before they destroy city landmarks), and Free All Monsters! [85] (mobile location-based AR game where player-created monsters are placed at different locations/times). The findings from the studies conducted using these games are similar to the findings from studies conducted using commercial locative games. With Gaea they found participants socialized, which increased enjoyment and learning with how to recycle. Free All Monsters! utilized user-generated content to scale the game to more locations. In Martians from Outer Space, they encountered technical challenges stemming from the medium (public display) they used.

2.2.2 Guidelines for Creating Locative Media Content

Even as locative media becomes more popular, how to create locative content is not well understood. The interface and feature set of a locative media tool will influence how the content is created. Although Story CreatAR does not provide specific recommendations for authors on how to shape and create their content, we can provide training materials based on the guidelines presented in this section.

Millard and Hargood [94] use co-operative inquiry on a narrative they created ("The Isle of Brine") to derive guidelines for locative narrative and tools that support it. They found authors should consider the pragmatics of the location such as how viewers would move to locations (i.e., considering transportation and accessibility), where bottlenecks occur, and the meaning of the location should be integrated in the narrative. Second, they found authors should consider aesthetics of the location such as locations of interest, the point of view in the story, and the impact of the space on the tone/theme of the story. Interestingly, the prediction of participant trajectory and bottlenecks can be partially explained with spatial analysis techniques that Story CreatAR employs. Spatial analysis can also shed light on point of view in the story and the impact of space on tone/theme. Some aspects of the aesthetics of space are spatial, while others have more to do with colour, decoration, materials, and the meaning ascribed to the space.

According to Neustaedter and Tang [98] there are many aspects authors should consider when creating locative media content. First, consider the *physical limitations* of your audience [98]. Is the experience designed for elderly people? Then, authors do not want the users to move long distances or to go up steep hills. Alternatively, if the experience is for youth, then authors could include longer distances and steeper hills. Second, a similar aspect to physical limitations is *stamina* [98]. The longer the experience is, the more tired the user will become. Thus, authors might want to consider having difficult tasks at the start when the user is less tired, or breaking up an experience. Third, there are also *legal limitations* that need to be considered when creating locative media [98]. For example, the experience should not involve users walking on private property. Lastly, content creators need to consider the *safety* of users [98].

Through locative media projects, Longford [84] determined several additional design considerations for content creators. How does someone feel in the space (e.g., an abandoned building may create suspense)? How do humans impact the space (e.g., a busy street causes a lot of noise)? How does time impact the space (e.g., can something in the space be added/removed and how does that impact the experience)? How does the space change over time (e.g., in the afternoon the space is bright, but at midnight the space is dark)? How do users comply by the rules and policies of the space (e.g., in a library users need to whisper)? Who do we need to consider and consult for the space (e.g., we may need to consult a principal to use a school classroom)? These considerations are important for people who create the content and for people who deliver the content to end-users.

Azuma [29] provides three research-based design strategies for designing locative AR/VR experiences. First, use augmentations to improve an interesting environment. Second, re-purpose an existing environment to fit your story. Third, choose an environment and then retell its stories. Each of these strategies can be used for Story CreatAR. However, Story CreatAR's ability to define rules once and deploy anywhere favours Azuma's second approach. For example, in the first strategy authors would design a story that utilizes the context of the environment. In the second strategy, authors can design a story that is context-independent of the location. For the third strategy, authors can design a story based on knowledge of the location.

Packer et al. [103] examined 13 locative stories and held interviews with 34 people as readers of these stories, which resulted in guidelines for a locative media toolkit. According to Packer et al. [103], authors must consider *deal breakers*, *pragmatic considerations*, and *aesthetics*:

1. some *dealbreakers* to consider are where to start and begin the story, the effort for a user to reach a destination, and how long it takes to read the story compared to how long the experience lasts. Authors in Story CreatAR can choose the player's start and end position and their effort to experience the story through spatial rules, control over story length, and content length.

2. some *pragmatic considerations* include how the landscape controls user trajectory, consider bottlenecks in the experience, specify high cost locations to be optional or bonus (e.g., top of a steep hill), and consider how safe and accessible the location is. In Story CreatAR, we can consider some of these pragmatic considerations through the use of space syntax, and

3. some *aesthetics* to consider are physical points of interest (e.g., landmarks), how the time, season, place, etc. impacts the space, how to hold the reader's attention, and what distractions they may encounter. A site-administrator may consider these aspects and adjust a story created using Story CreatAR accordingly.

Hargood, Charles, and Millard [66] provide locative media recommendations based on literature gaps. They recommend separating narrative and locative structure, as done by StoryPlaces. They find candidate locations local to the reader which meet author-defined requirements. After determining candidate locations, content is matched to the most suitable locations in the reader's area. Story CreatAR uses author-specified spatial rules to find a location that meets requirements. However, it does not clearly separate the narrative and locative structure as the logical flow and constraints in the story rely on the location of the experience.

Naliuka et al. [97] propose a narrative architecture for location-based experiences. They propose using missions, a set of challenges in the story that are affected by events and are activated/deactivated based on satisfying preconditions. They verify their architecture using a case study of a game called *Viking Ghost Hunt*, which allows players to use their mobile device to hunt ghosts in AR. This architecture reflects the approach Story CreatAR takes: it is clear to see the translation to storytelling where a mission (story) consists of a set of challenges (sub-plots) which are affected by events.

2.3 Narrative Theory

Storytelling plays a critical role in culture and entertainment. Narrative theory [108] is a way to understand storytelling. Artistotle [61] is among the first to build theory around dramas. His theory encourages story progression through a beginning, middle (climax), and an end (resolution). We discuss aspects of narrative theory that have influenced the design of Story CreatAR, and the ability of the tool to support different aspects and forms of narratives, as considered through the lens of narrative theory.

There has been a long debate over whether and how storytelling is present in games [21]. For the purposes of this thesis, I consider that storytelling is present in games and I will discuss literature on the role of narratives within games. We lack a detailed understanding of the role of narratives in games and how narrative elements can be combined effectively with game elements [21]. *Ludo-narratives* are roughly defined as the intersection of narrative elements and game-like features. Aarseth [21] aimed to further understand the structure of ludo-narratives by examining five ludo-narratives. Aarseth creates a model based on four independent dimensions they find in ludo-narratives: events, objects, locations, and characters. They find characters can be a powerful way to create ludo-narrative content. Each of these four dimensions are fundamental in Story CreatAR and Story CreatAR specifically generates avatar-based narratives as characters have been shown to be effective for content creation.

Wei [135] also explores how narratives are embedded in games. Wei creates a descriptive framework based on narrative theory and explores how the framework can be applied to some game narratives (e.g., The Legend of Zelda, Prince of Persia: Sands of Time, Grand Theft Auto). Wei suggests three ways to embed a narrative in a game: *horizontal embedding* (shift in who tells the story such as through an object talking), *vertical embedding* (shift in who tells the story and the actual storyline, such as non-player characters (NPCs) telling side stories to the viewer), and *modal embedding* (change in the world such as showing a dream). Story CreatAR permits each type of narrative shift by allowing flexibility in the way the game world appears and providing numerous voice actors which can speak custom voice lines.

Similarly, Dormans [48] comments on narratives in games in terms of three key characteristics: *interactivity*, *simulation*, and *gameplay*. However, these characteristics are heavily reliant on the medium used to tell the story (e.g., an AR headset allows participant movements to cause game interactions). Therefore, Dormans suggests that the gaming medium should influence the story. During the creation of Story CreatAR and as our authors wrote their stories, we made suggestions to authors stories based on the technical limitations and potentials of the medium. For example, we suggested using proxemics to trigger an event. Cardona-Rivera, Zagal, and Debus [38] present the GFI framework, which states narrative designers must be concerned with goals (player motivations), feedback (result of player inputs), and interpretation (player emotions based on what they think about). Authors of Story CreatAR could follow the GFI framework by providing authors with feedback for user input. For example, MRTK supports optional voice command feedback through a textual pop-up of the of the voice command being recognized.

There have been many interactive narratives inspired by interactive storytelling (IS) theory [61]. Interactivity is important for AR/VR experiences to increase immersion and to provide a degree of control to the audience [126]. Propp [61] introduced narrative concepts derived from Russian folktales: *narrative functions* are a basic unit of narratives (actions) used to describe Russian folktales. There are 31 functions associated with seven different character roles: "hero, villain, donor, helper, dispatcher, sought-for person, and false hero" [108]. Propp also explains that all 31 functions are not found in one fairy tale, but the order of the functions will always be the same. For example, if the hero is kidnapped, they will always eventually escape. The functions provide a model for narratives more generally, which have been used in many IS, but lack character perspective and emotion. Greimas [61] categorizes characters based on oppositional terms (e.g., helper vs opponent) and semantic fields (e.g., angry, jealous, etc.). However, there has been limited use of Greimas's theory in interactive storytelling (IS) in practice, perhaps due to its complexity. Barthes describes narrative units semantically by five codes: ACT (ACTion) represents an action in the story, REF (REFerence) requires background knowledge to properly understand, SYM (SYMbolic) represents meaningful cultural objects (e.g., churches, human body), SEM (SEMantic) refers to the implications of the word choice, HER (HERmeneutic) refers to text that requires interpretation by the reader. ACT and HER codes are important for IS as they are used to create suspense. Authors will implicitly use these theories when creating an immersive locative AR narrative, but may not explicitly characterize them using the terminology of a specific narrative theory. Therefore, Story CreatAR ensures that the various dimensions and components described in the theories are possible to generate. Story CreatAR has an event system to progress the story (i.e., allows authors to create the three story arcs) and allows different ordering of narrative components (Artistotle's and Propp's theories), the ability to create oppositional characters as suggested by Greimas's theory, and a way to categorize/label narrative components that may reflect Barthes codes.

In order to design an authoring tool, it is important to have a basic understanding of narratives. Genette [58] defined 5 main components in narrative structure.

1. *Order* refers to the difference between chronological order and how the narrative is told. Preconditions in Story CreatAR can be used to order events, where an event waits until its preconditions are met before execution.

2. *Duration* refers to the difference between how much time passes in the story and how long it takes to read the story. Timer events in Story CreatAR can be used to add time-stamps to the story that events can use, however, authors can not control whether a viewer sees an event and can only control the maximum time a viewer may see the event.

3. *Frequency* refers to the difference between how often an event occurs in the story and how often it is mentioned to the reader. You can repeat an event in Story CreatAR to increase its frequency. Similar to duration, a certain frequency of an event may occur in the story, but that may differ from how often the viewer experiences the event.

4. *Mood* refers to the atmosphere of the narrative. Mood can be influenced by when (time of day, weather, time of year, etc.) and where the story is experienced, which is up to the author's discretion. Authors may also use Story CreatAR features to influence mood such as character animations, appearances, and dialogue lines, and the furniture and decorations present in the experience.

5. *Voice* refers to who narrates the story and what point of view it is being told from. Authors have control of the voice in Story CreatAR by specifying who says what dialogue lines.

Genette [108] also differentiates how to view characters and events: *internal focalization* which shows the internal thoughts and feelings of one or several characters, *external focalization* shows character's external dialogues and actions, and *zero focalization* where it is unknown where/whom the narrative is narrated from. Focalization can be created through the assets (characters, objects) and audio files used in Story CreatAR, which can be customized to the suit the author's story.

Carstensdottir, Kleinman, and Seif El-Nasr [39] consider the interaction design model for IS in games. They discuss different types of interactive narrative structures. *Linear narratives* progress in chronological order with one possible start and end point. However, one consequence of using a rather simplistic linear narrative is the lack of replayability. *Nonlinear narratives* defined as narratives that do not occur in chronological order, perhaps due to cycles in the story, foreshadowing (hinting at something that will happen in the future), multiple story paths, etc. offer replayability. Note that it is important that Carstensdottir, Kleinman, and Seif El-Nasr are considering narratives in games, which is why replayability is important. Replayability may be less important for pure narratives. Nonlinear narratives are supported in the story through the viewer's choice of where to position themselves, where to look, and other forms of user input (e.g., voice commands, hand gestures, gaze). For example, when the viewer walks through one of three doors, they choose one of three narrative paths. The following are types of nonlinear narratives. *Branching narratives* are more complex to implement as there are different paths that players can choose which lead to vastly different endings. *Foldback structures* are structures where the narrative can diverge based on player input, but will eventually return to follow the original story line. *Broom structures* are structures that begin as a linear narrative and only at the end provide branches. *Hidden structure* refers to a narrative that consists of sub-stories dispersed throughout the experience. This lacks replayability, but offers high player agency as they control the order of events they experience. *Opportunistic structure* refers to structures that dynamically change based on what is happening. According to Carstensdottir, Kleinman, and Seif El-Nasr [39] this structure is not often used. Each of these narrative structures can be constructed using Story CreatAR through its ability to specify zero to many event preconditions.

Monfort [96] defines several nonlinear narrative patterns based on *Narrative Discourse* by Genette.

- *Retrograde* refers to events narrated in reverse chronological order.
- *Zigzag* refers to events being told at different times in the story.
- *Flashback* refers to events from the past.
- *Flashforward* refers to events that may occur in the future.

These narrative patterns involve careful event timing and ordering. Stories created by Story CreatAR may use these patterns by specifying the order of events. Monfort [96] implements an IS system that uses locations, characters, objects, and events. This system generates variation in the order of events, which can be categorized according to the nonlinear narrative patterns by Genette. This system has not been used in practice, but shows potential for ordering events arbitrarily.

2.4 Spatial Analysis Techniques

2.4.1 Space Syntax

Space syntax originated in the 1970s at the Bartlett School of Architecture, University College London (UCL) by Bill Hillier. *Space syntax* [30, 137] is a family of techniques for understanding spatial characteristics at a building or city scale. Space syntax is used by architects, urban planners, and others to predict and understand human movement behaviours, social interactions, and spatial qualities. It is fundamental in space syntax that the social space can not simply be mapped to a physical space, but that both the social space and the physical space affect each other. Space syntax aims to describe how the social space can be described by the physical space. Steen [125] examines seven offices with over 1500 workers and finds that visibility and closeness (distance) of co-workers encourages interaction in office settings. For example, managers may be found in the most visible area of the office. Other work similarly shows how social behaviours [52, 53] and movements [100] can be affected by space syntax placement.

Yamu et al. [137] and Bafna [30] provide a brief introduction to space syntax. Space syntax uses several spatial terms and techniques to quantify various spatial characteristics. Space syntax analyzes a *configured* space, which is formed by turning an environment into a set of connected units. The configured space is then turned into an appropriate graph. In a related office example from Bafna [30], the spatial layout can explain the social configuration. If there are two offices side-by-side and the user needs to go through one office to get to another, this could indicate that the first office may be for an assistant and the manager may be in the further office. An important part of the layout is what one person can see from their position. For example, an associate may want to have a view of the entrance to see people walking into the building. For the associate to see the entrance, it needs to be an enclosed space where both positions can see one another. This is a known space syntax term, *convex space*, which refers to a convex polygon (enclosed shape bordered by straight lines) in which all points inside the polygon are visible to all other points. A *convex map* can be generated by taking the minimal amount of large convex spaces to cover the environment. A convex map can be calculated by finding the largest convex spaces until the entire environment is covered. Then, this is translated into a graph by replacing convex spaces with nodes and routes between the convex spaces as edges.

A space syntax concept focused more on lines of sight and mobility is called an *axial map*. An axial map consists of the least amount of *axial lines* to construct the environment. An axial line is the longest straight line that connects two convex spaces. The axial lines represent a node in the graph and the intersection of axial lines represent an edge. Convex maps are used to represent the spatial characteristics, whereas axial maps are used for understanding behaviour characteristics of the space. For example, Li, Barbieri, and Querica [83] use an axial map along with other techniques to control navigation in the city using contextual factors.

Another property of space syntax is known as an *isovist*, which can be used to describe visual information in a space. An *isovist* refers to the volume of space visible from a given point. This can be more easily understood as the space occupied by the light visible by shining a flashlight 360° around a particular point. One application of isovists has been to determine the placement of shared displays in a medical environment. Scupelli, Kiesler, and Fussel [118] investigate the effect of an isovist on visibility and to some degree the social behaviors that take place in the setting. They examine mutual visibility (isovist overlaps) values at two operating room suites of a media display for nurses and doctors and find that higher isovist overlaps indicates more interaction with the display. This is one use of an isovist, however, in Story CreatAR we use other isovist-based values.

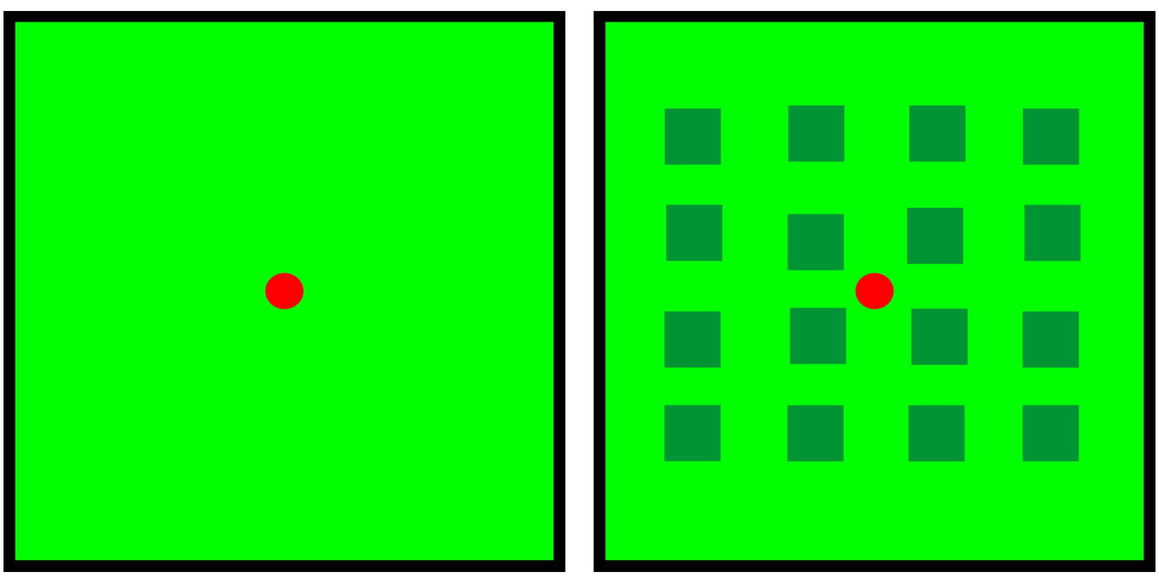


Figure 2.1: Left: a field with low visual complexity and high openness. Right: a forest with high visual complexity and low openness

We can derive three isovist-based space syntax characteristics used in Story CreatAR. First, *visual complexity* is calculated from the perimeter of the isovist and roughly measures the amount of vantage points that can see the user. Second, *openness* is calculated from the area of the isovist, which represents the visible area around a point. To make the difference between these characteristics clearer, we will go through the example shown in Figure 2.1. We have two spaces with the same physical area and we are at the center position shown by the red dot. The left image shows a field and the right image shows a forest, where the dark green boxes represent trees. The area of the isovist (openness) on the field will be the entire square. However, the openness of the forest will be smaller as it is fragmented by the trees and the user can only see small slivers between them. Notably, these slivers of sight will create a large perimeter. Therefore, the field shows high openness and low visual complexity and comparatively the forest shows low openness and high visual complexity. Third, *visual integration* can be derived from the number of isovist intersections required to get from point A to point B. Visual integration roughly refers to how visible a node is to all other nodes. For example, in the intersection of two hallways there is high visual integration as many nodes can see that node. In addition, we have used the space syntax characteristic *connectivity* in preliminary works. Connectivity refers to the number of directly connected edges at the current location (node). Connectivity can be calculated in one of two ways: the number of immediately accessible convex spaces or the number of intersections for a given axial line. A room connected to many rooms will have high connectivity, whereas a room that has only one connection will have low connectivity.

Some other useful characteristics derived from space syntax analysis include, but is not limited to:

- *gate count*: the likelihood an agent[1] will pass through a location,
- *traffic*: the likelihood that a line will be used during traversal,
- *accessibility*: how easy it is to get to a room from all other locations, and
- *minimum radial length*: how close a location is from a wall.

Gate count could be used to identify bottlenecks in the space, which could influence the mood in the story (e.g., crowded space with bottlenecks could create suspense).

[1]An agent-based simulation involves a computer-agent that moves according to space syntax analysis, predicting how humans will move through the space.

Traffic can be used to determine a normal route for an NPC to traverse as opposed to a sneakier/quieter route. Accessibility can be used to place objects or events. For instance, a vault may be stored in a location that is not very accessible, but a customer service area may be placed in a highly accessible area. Minimum radial length can be used to determine placement close or far from a wall. For instance, a bed may be placed close to the wall.

Using space syntax for locative narratives provides distinct benefits, but also poses challenges [102]. Some advantages of space syntax are that it provides numeric values for seemingly qualitative spatial aspects, which offers quicker and simpler analysis, and reduces the need for an author to visit a space in order to identify such aspects. Since space syntax converts the spatial layout to a type of graph, this can leverage the extensive history and knowledge from graph theory and algebra. The quantitative spatial values can be used by space syntax theory to predict social behaviours and movements, which can be useful not only for placing characters and events, but also for understanding how viewers are likely to explore and traverse a locative narrative. Despite space syntax's relatively long history, there have been several criticisms to the theory. Space syntax considers the relationship between the interior of a building and its immediate outdoor area, which is a problem in non-Western structures where the immediate outdoor area is a public space (can not use the outdoor area in path calculations) [102]. Therefore, the applicability of space syntax can change between cultures. Another issue with space syntax is that it considers all types of connectivity the same (e.g., short and long hallways, archways and doors, etc.) [102]. This can have implications for placement and movement using connectivity as the connectivity values may be misleading towards how connected the space is, perceived effort to get to a location, and how segregated a space is. Additionally, Osman and Suliman [102] argue that space syntax simply transforms the physical environment into a graph which does not contain information about the social habits that take place there. Although, space syntax provides some indication of social behaviours based on space alone, it is important for authors using Story CreatAR to understand that it provides *predictions* of human flow and behaviours, rather than a *comprehensive* understanding.

There are many tools used to perform space syntax analysis such as QGIS [10], Grasshopper [27], and depthMapX [43]. However, we use depthMapX in Story CreatAR, which is shown in Figure 2.2. DepthMapX is an open source tool from the Space Syntax Labortatory, UCL that began in 1998 and has been further expanded by Tasos Varoudis. DepthMapX can perform spatial analysis at a building or city scale, however, we use it at a building scale. Story CreatAR uses depthMapX through a command-line interface to generate space syntax values for a floorplan.

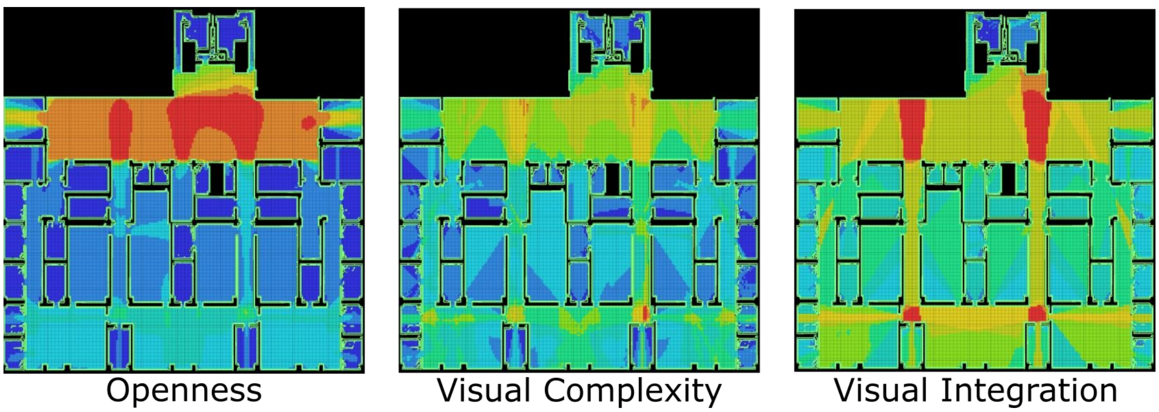


Figure 2.2: Space syntax characteristics produced by depthMapX where red shows high values and blue shows low values.

2.4.2 Room-based Analysis

Room-based analysis uses convex analysis to identify rooms in a floorplan. Several techniques for conducting room-based analysis exist with inputs ranging from vector graphs [46] to a 3D model [101]. Room-based analysis is used in Story CreatAR to defines rooms as a placement constraint. Other uses of room-based analysis can be for detecting number of doors in a room or determining directly connected rooms.

Architecture Floor Plan (AFPlan) [136] is an open source floorplan analysis tool created by Alexander Wyss and Florian Bruggisser. The goal of AFPlan is to quickly analyze a wide range of floorplans and produce accurate (84% on average, 95–100% with supplementary user interaction) room identification results. Story CreatAR exposes the room detection ability to authors through object placement constraints.

2.4.3 Proxemics

Proxemics [23, 24, 32, 59, 60, 63, 86] was created by Edward Hall in 1966. However, the use of proxemics in HCI research and to aid human interaction with technology is relatively new. *Proxemics* refers to the distance and orientation relationships between devices and people. As HCI research has been facilitated with new developments in position/orientation sensors, the need for research on proxemics grows. Moreover, with new technologies like AR and VR these interactions need to be considered as they can increase immersion.

There are four types of proxemic distances which can change based on time, space, and culture: *intimate*, *personal*, *social*, and *public* as illustrated in Figure 2.3. *Intimate* space (less than 1.5 feet) is the closest space shared between two people such as couples. *Personal* space (1.5 – 4 feet) is the space occupied by friends. *Social* space (4 – 12 feet) can be the space occupied by a group of people such as for an office meeting. *Public* space (12 – 25 feet) is the largest space occupied between people such as strangers in a park.

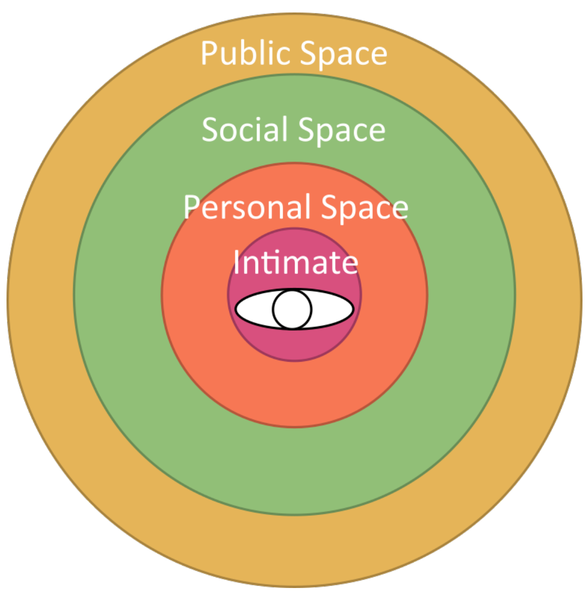


Figure 2.3: From largest to least distance: public, social, personal, and intimate space.

The theory of proxemics has generally been considered for humans, however, Llobera et al. [34] research how people interact with virtual characters. They have groups of one to four virtual characters approach people at different proxemic distances. They find that the closer a participant is to a virtual object or character, the higher engagement they have. Additionally, it is important for authors to consider what proxemic behaviour the physical environment allows (e.g., some areas are restricted). For instance, a museum that has a dinosaur model may not allow museum goers to get within 10 meters of the dinosaur. Therefore, the virtual experience can not reasonably ask viewers to get within five meters of the dinosaur to trigger an action.

Several researchers have built proxemic-aware systems ranging from public displays to art installations. *The Proximity Toolkit* [86] exposes the proxemic relationships used by the low-level sensors, but the developer still needs to manually check entities and their local state. *ProxemicUI* [23] takes it one step further by exposing the relationships through proxemic-based events. ProxemicUI is an in-house open source framework used in Story CreatAR to declare proxemic events between the player and NPC conversations. ProxemicUI is a framework consisting of tracked entities (e.g., the player, NPCs, objects), proxemic rules (e.g., distance between player and NPC is less than 5m), and proxemic events (e.g., when the proxemic rule is true, an event will occur). The tracked entities send their position and orientation data to ProxemicUI through Open Sound Control (OSC) messages. ProxemicUI uses the OSC messages to create proxemic events, which are triggered when the tracking data meets the user-defined relative/absolute distance/orientation rules. Moreover, rules can be combined to create a compound proximity rule using and, or, xor operators or negated using the nor operator. We use several proxemic rules in Story CreatAR: relative distance and orientation rules are used to trigger conversations.

An important consideration when using proxemics in AR experiences is the field of view (FoV) of the medium. Microsoft provides guidelines for comfortable placement of virtual objects [51] (which involves seeing the entire object). The HoloLens 2 has a 54° diagonal FoV. They suggest the optimal placement of virtual content is around 2 meters. However, if the content must be placed closer, then stationary content is preferable over moving content. This suggests for players triggering events and story content based on distance triggers that the player should trigger the story component about 2 meters away if possible.

2.4.4 F-formations and Territoriality

F-formations [42, 57, 70, 75, 87] describe the spatial relationships (described by position and orientation) between people in social spaces. F-formations are based on how people arrange themselves with respect to others and the space. F-formations theory can be used to find situations where people typically arrange themselves in a certain way. This can be used in immersive AR narratives to arrange NPCs in a realistic manner given the situation.

There are three different social spaces (Figure 2.4): *o-space*, *p-space*, and *r-space*. *O-space* is the space where social interaction occurs. *P-space* is the space where objects involved in the interaction are. *R-space* is the space that is not included in the O and P space. The R-space is not used by people interacting with one another, but it is used by people wishing to join the F-formation. Some examples of F-formations are people walking side-by-side, people eating at a restaurant, and people waiting in a line-up.

Marshall, Rogers, and Pantidi [87] describe different types of F-formations: circular, rectangular, semi-circular, linear, facing (two individuals), L-shape (two individuals form a 90° angle), and side-by-side. These refer to people or objects being arranged in these shapes. Notably, space can play an interesting role on how F-formations work. For example, if two people go up to a desk, they can stand side-by-side with equal access to the desk. However, when six people go to a desk, they can stand-by-side, but only the two people in the middle will have equal access to who is at the desk. Often, F-formations will change based on how many people are involved.

There is related research which uses circular F-formations to simulate avatars in conversation in VR [104, 116, 82], which is shown to create realistic scenes [104]. Hedeyati, Kennedy, and Szafir [70] examine how F-formations change when a virtual moderator compared to a physical moderator is present in a group conversation. They find that humans stand further away from another human than they do a virtual moderator. In Story CreatAR we currently use the circle F-formation to arrange avatars in a conversation. We use proxemic distances specified by the author to trigger when avatars or a group of avatars talk to you. These distances are currently based on the four types of proxemic distances, but could potentially be closer distances as it involves virtual content. However, the limited FoV of AR devices such as the

HoloLens 2 has implications for F-formations as well: we may want all objects/avatars to be arranged in such a way that the viewer can see them all at once.

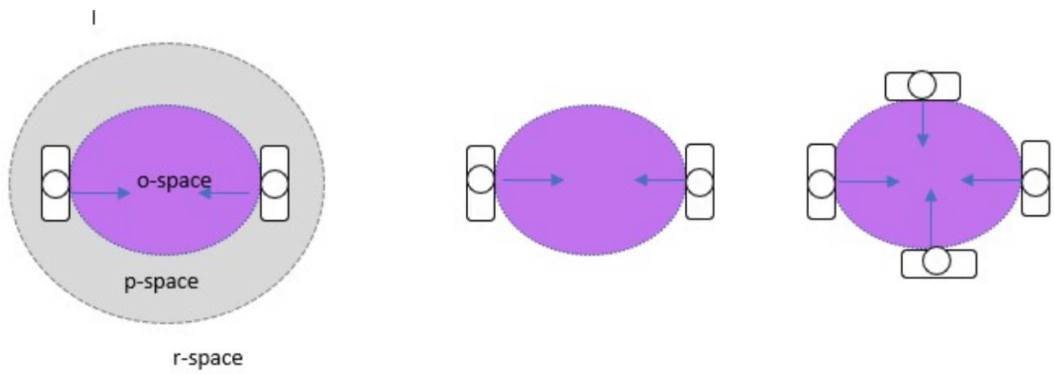


Figure 2.4: Left: Visualization of o-space, r-space, and p-space. Middle and right: Different F-formations.

Scott and Inkpen [117] performed two observational studies to understand the role that partitioning of territories plays in the collaboration process in a formal and informal tabletop setting. In both studies they found participants made use of *personal* (area closest to participant), *group* (available for group space), and *storage* (items stored there) territories. These territories varied in terms of size, shape, location, and functionality. *Personal* territories are generally reserved for participant's own use, and the size and shape of personal territories can be influenced by the number of collaborators and how they were arranged, size of the table, intended function, and physical barriers. *Group* territories are used to perform main tasks, and consist of the space on the tabletop not occupied by personal space. *Storage* territories are used to store resources, which moved to the tabletop as the task progressed. They provide several recommendations for designing collaborative tabletop experiences: allow people to see both personal and group activity, provide a collaboration space that is large enough, provide resources related to tasks that should be done in different territories (e.g., pen and paper in personal space for taking notes), and allow participants to customize where to place items. We consider both territoriality and F-formations as we adjust avatar formations based on number of avatars (i.e., adjust size of overall F-formation and distance between avatars), the F-formation desired (e.g., circle formation), intended function (e.g., conversation between a couple has smaller distance), and physical barriers (e.g., conversations can be manually moved by an author to account for physical barriers such as walls). Further work has been done on territoriality and behaviours around large public displays [28, 105, 131, 132, 134], but is out of scope because the experiences we generated are only evaluated in a controlled environment.

2.5 Space-Adaptive Considerations and Applications

A key challenge in creating augmented reality content is adapting the content to different locations. To understand this challenge, consider designing how furniture are placed in a living room. For your house, this is simple, authors can just move objects according to what they like. However, if authors want to generalize the placement to their neighbours' houses, this would either be time-consuming to do manually or difficult to create a generalized method for adaptive placement. That is why some research explores how to adapt an AR/VR experience based on the spatial characteristics of an environment. We consider how this can be applied specifically to locative AR/VR experiences.

One spatial consideration is the size of rooms and amount of furniture. Shin et al. [120] looked at the effect of room size (small/large) and furniture amount (fully furnished/scarcely furnished) on an AR experience. They found participants treated virtual game objects and characters how they would treat them in real-life. This is an important consideration for authors using Story CreatAR (e.g., participants would stand back from an NPC).

In another study, Shin et al. [121] investigate the effects of traversability and visibility on user experience by comparing different rooms that vary in terms of room size (small/large) and layout of furniture (peripheral — along the walls, scattered — random, and centered). They suggest that large rooms should have furniture placed in the center for higher presence and usability. Shin et al. suggest to not only consider the spatial configuration, but also the semantics of the location and integrate that within the storytelling.

FLARE (Fast Layout for Augmented REality applications) [55] is a toolkit developed by Microsoft Research in 2014. FLARE uses *declarative rules* to map virtual objects to the physical world for indoor AR applications. The declarative rules provide constraints on relationships between different content, between the content and the player, and between the content and the space (e.g., walls, floors, furniture). FLARE uses a depth sensing camera (e.g., Microsoft Kinect) to identify the geometry of a room and performs on-the-fly placement of virtual objects within the physical room based on the declarative rules. Story CreatAR similarly aims to dynamically place objects in accordance with it's spatial configuration. However, Story CreatAR differs: FLARE provides precise single room placement in real-time based on room geometry whereas Story CreatAR provides general building-scale placement based on space syntax values before the experience starts.

Scenograph [88] is an application that allows designers to create a walkable VR experience that fits the constraints of the physical space. Scenograph represents the user-defined content as a graph where spatial nodes represent scenes and logical nodes represent story progression, which are connected by transitions. Scenograph allows users to define spatial requirements regarding an object's size and desired placement within a room (e.g., by a wall, in the center of the room, etc.) and uses those to map the experience to the physical space. In contrast, Story CreatAR maps virtual content to the entire physical space using spatial analysis.

VRoamer [41] is a tool that dynamically creates a walkable building-scale VR experience displayed in the Acer Mixed Reality headset [14]. VRoamer uses an Intel RealSense D435 RGBD camera [20] to provide depth images, which can be used to scan the physical environment for rooms and obstacles. The physical rooms and spaces are matched with pre-generated virtual rooms and corridors. Physical obstacles are replaced with virtual obstacles, however, a notable issue is with objects in the periphery where the field of view cuts off and thus are undetected by a user. Story CreatAR mirrors VRoamer with having a walkable building-scale experience. However, Story CreatAR differs by finding optimal placement based on spatial analysis for a building-scale rather than greedy placement and Story CreatAR does not require object avoidance as the target platform is AR.

Dreamwalker [138] creates a walkable immersive VR experience by finding a physical path that closely matches the virtual trajectory and places virtual objects where physical objects may exist. To operate the experience, users require a Windows Mixed

Reality headset and controller, a GPS, depth cameras, batteries, and a PC. Comparatively, Story CreatAR places content based on spatial relations and the viewer in Story CreatAR does not have a predefined path.

Kán and Kaufmann [80] present an algorithm for automatically placing furniture based on interior design rules. The design rules range from how much space should be around the object, how likely it should be against a wall, relationships (e.g., distances) with other objects, rooms it should be located in, and how many of it should appear. Their algorithm is similar to Story CreatAR in several ways: it places big furniture first and then uses another algorithm for decorations (e.g., doors and windows). In Story CreatAR we would place furniture first and make small manual adjustments to the placement. Objects being placed by their algorithm requires design rules to be specified. In Story CreatAR, a placement rule can be associated with an object in the interface. Kán and Kaufmann are generating placement at a room-scale, whereas we generate placement at a building-scale.

Wang et al. [133] present DistanciAR, which is a tool for remote authoring using a tablet so that authors can create site-specific AR experiences (by interacting with a 3D reconstruction) from another location. They scan their environment using a LiDAR scanner, then remotely arrange the story/furniture, and test it with a consumer. They gathered initial feedback on the tool from professionals, which resulted in the addition of two new features/modes: DOLLHOUSE (bird's eye view) and PEEK (photorealistic composite of the virtual objects) and an improved baseline called PORTAL mode. They found participants (authors) enjoyed the experience, but they encountered some complications (e.g., they would walk into a wall when testing remotely). Unlike previous applications, Wang et al. [133], like us, expect to test the experience remotely. However, Wang et al. have limited options for creating content that would result in a simple story (e.g., they do not offer rich story features such as proximity triggers, animations, and interactive behaviours).

Space syntax has limited use in walkable AR experiences to date. Reilly et al. [111] present a spatial analysis algorithm and two walkable immersive AR games, AdventureAR and ScavengAR, created by another Dalhousie student and me respectively. Both games use the spatial analysis algorithm to place game assets. The spatial analysis algorithm considers three space syntax characteristics: openness, visual complexity, and connectivity. The placement algorithm has been adapted to fit the needs of Story CreatAR: extending the space syntax characteristics used and supporting other types of spatial constraints (e.g., rooms).

Several tools and applications exist that try to address the challenge of mapping content to different or unknown locations. Some solutions have overlapping properties (e.g., considering the spatial configuration, testing in VR), but the methods used to map content varies greatly. More work needs to be done to effectively provide a comprehensive tool that authors can use to create locative content for both site-specific and site-agnostic experiences.

2.6 AR/VR Narrative Tools

There has been research regarding tools that permit the creation of AR/VR narratives for different skill levels. Minimal programming knowledge is required for authors using low-fidelity tools, however, for higher-fidelity tools authors often require some components to be programmed [78].

Zhang, Hinze, and Vanderschantz [140] create a prototype for mobile AR that guides users with markers to physical locations to experience parts of the story. Their experimental results indicate that the viewer should be notified when they arrive at a particular location, previously seen stories should be removed, and more context than markers may be useful for navigating. Stories created in Story CreatAR utilize movement based triggers to begin events, which perform an action that lets the user know they are at an appropriate location. Story CreatAR provides context (e.g., furniture) for the location, which can help with navigation. For example, an author may want to display a map of the floorplan in the experience.

Hargood et al. [66] propose (but do not implement) a locative narrative tool framework which considers spatial analysis to remap content in a way that makes sense (e.g., content may not make sense to be mapped to a location that is hard to traverse to). They describe several challenges that still need to be addressed by locative media: how to describe locations in terms of where to place story content, how to map locations to story content, how to provide an interface for the mapping, and how to integrate storytelling theory and knowledge into this system. Story CreatAR follows a similar implementation to the one proposed by their framework. Story CreatAR provides a rule-based association of narrative elements and spatial locations, which can automatically be remapped to different locations for the experience.

Tanaka and Gemeinboeck [128] propose a framework for designing locative media that maps interaction and location data to the experience. For example, they use mic and camera data from participants to render a video based on their mobile devices and audio based on predetermined music or live participant audio. While they propose a semi-automatic framework for musical and audio-visual art, we draw from spatial analysis. One aspect of their framework is having the data be recreated based on participant movements (GPS data). However, Story CreatAR uses spatial analysis for the most prominent aspects of the tool, which allow for space-adaptive placement.

Twine [13] creates a narrative using a node-based representation. Twine requires additional coding to account for complex features such as media, various types of events, etc. In comparison, Story CreatAR reduces the barriers for non-technical authors by providing a graphical user interface that provides access to some sophisticated features. However, advanced features unsupported by the tool require programming knowledge (e.g., customizing the appearance of the narrative requires use of cascading style sheets, CSS).

Abawai, Reinhold, and Dörner [22] propose an authoring toolkit to make creating narrative experiences in Mixed Reality (MR) more accessible to authors without a technical background. They provide different components, each with a different look and behaviour for the author to use, which allows for flexibility in creating the story. For example, a component could be objects, interaction components, cameras, etcetera. Some tasks the author needs to do are choosing and combining components, adding and creating multimedia content, and getting the visual components to match real world objects. Components have the ability to interact with one another. Additionally, there has to be a way for objects to be placed and manipulated (size and orientation) in the virtual world to reflect where they are in the real world. The goal of Story CreatAR is similar, in making locative storytelling more accessible for authors, however, we aim to achieve this through spatial analysis.

2.7 Impacts of viewer movements, position, and perspective in AR

AR is a medium that is gaining prominence for storytelling and some consider it a successor to the traditional cinema experience [33, 50, 114]. Mateer [47] explains this connection as "cinematic virtual reality, [an] experience where individual users can look around synthetic worlds in 360°, often with stereoscopic views, and hear spatialized audio specifically designed to reinforce the veracity of the virtual environment". Movies have the benefit of being able to be experienced at almost any locations and can be edited to achieve sophisticated world building, but are often displayed in 2 dimensions. Theatre has the benefit of being 3-dimensional, provides rich 3D animations, and special effects (e.g., spraying water on theatre viewers during a swimming scene), but it does not allow for editability and it is not very expandable (in terms of modifying the current location and changing locations). However, AR storytelling inherits the benefits of both movies and theatres. Viewer perspective and position, and content position is important in cinema with respect to the location, which is controlled by set design and camera angle. Thus, it is also important for AR storytelling.

Cinema and theatre are similar in terms of using interpersonal spatial relations (F-formation and proxemic theory) to aid in the storytelling. Theatre practitioners are experts in using spatial cues to progress the narrative and to consider the relation between the viewer, the physical environment (stage), and the created narrative. Pope, Dawes, and Sheikh [107] examine how four theatre directors use spatial relationships of three actors to create a scene for immersive theatre and 360-degree filming. They find F-formations (e.g., a viewer may be arranged in a line with the characters to make them feel like part of the narrative) and proxemics (e.g., three characters are close together when perceived as a unit) can reflect social dynamics and affect the narrative experience.

Aristotle's theory [108] concerns *plots*, where a good (tragic) plot consists of a series of focused story events. Aristotle believes a good plot must be properly *made*, *ordered*, and *whole*. He emphasizes the importance of *made* by distinguishing between what belongs (e.g., a car accident) and what does not belong (e.g., the boring details of everyday life) in the narrative. This concerns the event itself and how it integrates with the rest of the storytelling. *The order* is important as the same event in a different position in the story, will have a different meaning. *The whole* refers to the set of events that make up a whole purpose. These aspects becomes even more critical for a continuous experience, where not only does the author have to consider what events are important for the narrative, but also how to direct the viewer's attention to these events. Moreover, in AR/VR authors give up a degree of control over the viewer (e.g., the viewer can eavesdrop on a conversation at any time), which can lead to a different order of events for different experiences.

Maintaining immersion can be difficult when the viewer has the freedom to move and look anywhere in the space. Pillai and Verma [106] examine immersion in VR storytelling with 99 participants who were shown a VR narrative called *Dragonfly* using an HTC Vive VR headset. They found the following aspects increased immersion with the participants: presence (the feeling of actually being in the virtual environment), spatial immersion (e.g., trying to look for something as it appeared in the space before), viewer agency (ability to control the story), and the story experience itself. This suggests that the medium (VR) and the storytelling itself are immersive. Story CreatAR aims to further increase immersion by providing appropriate placement of objects in the experience.

Bala et al. [31] examine how the location and the medium affect mobile AR storytelling. They evaluated a mobile AR story with 20 participants both on-site (virtual content integrated with the physical environment) and off-site (no integration); participants filled out a questionnaire on their experience. They found that flow ("fluency of performance" and "absorption by activity" [112]), presence, and narrative transportation (immersed in the narrative) were higher when at the on-site location. Although, these results are shown for mobile AR, it is not unreasonable to imagine that with head-mounted AR the results could be even more positive since it provides an immersive 360° experience.

Despite AR's relatively long history (beginning in 1968), the availability of consumer AR is rather limited [15]. However, AR has become increasingly popular, especially in educational applications [15]. A complete set of design conventions for maintaining continuity in an AR experience has yet to be explored. Barba [33] considers spatial scales as an important consideration for mixed and augmented reality experiences as the transition between scales can map to transitions in the story. Barba defines five spatial scales from smallest to largest.

1. *Figural scales*: space the human body occupies.
2. *Panoramic scale*: 180° view that can be seen by rotating the head.
3. *Vista scale*: what can be seen without rotating the head.
4. *Environmental scale*: what can be seen through walking.
5. *Global scale*: what can be seen on a map.

These spatial scales can help to make transitions in AR more seamless for the viewers, thus increasing immersion.

Struck, Bose, and Spierling [127] focused on creating an immersive 3D heritage experience. They found that the "situating" effect (viewer located within the story) requires time (1–2 seconds) for the viewer to situate themselves to understand the space and their perspective. Any story content presented during this time was lost. In addition, animations and movements help to engage the audience. Lastly, they were able to direct the viewer's attention by introducing a threat, which made the audience more aware of the space around them. Story CreatAR is able to account for the situating effect with the use of timers, which can delay events. Story CreatAR also helps to maintain continuity in the experience as the viewer is able to walk around the space.

Dooley also notes the need for viewers to become comfortable with the space at the start of an experience. Dooley [47] provides insights into designing VR experiences from interviews with three practitioners. Although video games have long employed 3D environments, in VR/AR the viewer is no longer facing a 2D screen, but rather is located inside the experience. Dooley emphasizes the need to direct viewer attention to events with audible or visual cues, notes that pacing of the experience can be unpredictable, and that viewers should be able to explore in their experience.

Similar to accounting for time to situate viewers, it is important to provide seamless transitions during the experience. Benford et al. [36] reviewed prior work and created a framework to understand continuous user trajectory. They refer to four critical dimensions: space (stage), time, roles (participant, observer, actor, technology developers), and interfaces (computers). It is important to maintain continuity at key transitions points such as the start and end of traversals, transitions between different roles and technologies, transitions between the physical and virtual world, and the time between different events. Content creators should devise strategies for managing continuity at these points. Story CreatAR uses spatial analysis to understand where and when the spatial transitions may occur, which can help maintain a continuous experience. To some extent spatial analysis techniques employed in Story CreatAR can be used to understand transitions between the physical and virtual worlds, however, knowledge of the physical world is only at a very abstract level.

Unlike other media (e.g., games), AR and VR specifically lack a standard set of practices and guidelines to follow. AR/VR content creators would benefit from guidelines regarding accessibility, properties of an experience, benefits/limitations of the medium, and maintaining continuity. Krauss et al. [78] interviewed 26 AR/VR practitioners to understand their methodologies. They found several challenges for AR/VR content creators: misunderstanding aspects of the medium (e.g., unaware of hardware constraints), lack of tool support (e.g., tool does not show the physical environment), and missing a set of common terms and methods (e.g., how to effectively design an experience).

There are clear guidelines for creating locative media [29, 66, 84, 94, 97, 98, 103] and some guidelines for creating an AR experience [33, 36, 47, 127]. However, there are a lack of guidelines for their conjunction. More research is required into the implications of viewer trajectory, position, and perspective on the spatial aspects of an experience.

2.8 Narrative Representations

There are a variety of methods to represent a narrative. We explore different representations to understand what types of representations authors produced when creating their story graph and how they may facilitate the translation of the narrative to Story CreatAR.

Aside from a script or written draft, the most common and traditional form of representing a story is through a node-based graph. Zeng [139] uses a node-based graph representation that encodes story metadata such as characters, actions, situations, and locations into the graph nodes and verticies. Ridel and Young [113] also use a node-based graph representation and they encode character actions as nodes, user interaction with the characters as transitions between nodes, and non linearity as branching in the graph.

Sharma and Rajamanickam [119] use an arc-based visualization, where arcs encode the duration of a scene, the day corresponding to the scene, and the relationship between characters in the scene. StoryCake [110] also uses an arc-based visualization where characters are represented as lines in the visualization, sessions are represented by different arcs, tags are used to identify different parts of the story, and colors are used to represent location blocks.

Story Explorer [77] demonstrates nonlinearity in a story using a two-dimensional graph. The x-axis represents the narrative order (the order the events are presented in the story) and the y-axis represents the story order (chronological order), which is divided into three sections: beginning, middle, and end. Story Explorer encodes several aspects of a narrative in the visualization including scene duration, character name, character gender, character dialogue sentiment, number of characters per scene, location of a scene, and time of day. The visualization offers a 2-dimensional graph view, a textual view, and metadata view. This provides more story relevant data in a way that is familiar for both story authors and technical users alike.

Node-based, arc-based, and two-dimensional graphs are useful for representing events in a story and encoding story metadata, but they typically do not show how a player experiences the story (e.g., events they see, their path, and where they are located).

A visualization of a viewer's experience can help show where viewers encountered confusion or which locations viewers did not visit. Visualize Your Spatial Experience [115] (VYSE) is one of many research projects that encode and visualize visitation/traversal patterns [45, 79, 90]. VYSE analyzes the experience of exhibition centre visitors based on shade encoding and path drawings of the viewers.

2.9 Summary

The review of locative media literature shows that most of the research deployments employ bespoke systems, and that general guidelines and platforms for locative media remain active research topics. However, I was able to ground the design of our tool on the findings presented by other locative media experiences and tools. I discussed relevant narrative theory in relation to Story CreatAR. I presented a brief background on spatial analysis techniques used by Story CreatAR. I examined other space-adaptive considerations and applications, as well as narrative tools for AR/VR, and establish that Story CreatAR is the first to use spatial analysis techniques from architecture (*space syntax*) and socio-spatial theory (*F-formations* and *proxemics*) to dynamically remap story content to different locations for an immersive AR experience. With the emerging medium of AR, authors are challenged due to the lack of control they have over the viewers. I examine guidelines for both locative media and AR individually, but find there is a need for locative AR guidelines, and argue that it is critical for authors to consider viewer perspective, position, and trajectory in AR to maintain a coherent experience. Finally, I survey narrative representations and how they can be used for authors stories or for representing a player's experience.

Chapter 3

Preliminary Work

3.1 Introduction

In this section I detail work from my undergraduate directed studies. The site-specific game (ScavengAR) that I created during my directed studies and the site-agnostic game (Adventure AR) created by another student functioned as proof-of-concepts for placing virtual objects using a space syntax rule-based plugin in a walkable AR experience. Both games were created in Unity [129] using an in-house plugin for object placement and deployed to multiple campus locations using the Microsoft HoloLens [91]. The games use a calibration system which aligns the virtual world with the physical world based on a QR code. Reilly et al. [111] describe this evaluation in detail. This work is important to include in the thesis as both immersive AR games are used as proof-of-concepts for using space syntax analysis to place story content in an immersive AR experience. The spatial analysis plugin used to place game elements in these games was later extended to be used in Story CreatAR.

3.2 Spatial Analysis Placement Plugin

A Unity plugin was developed by a different student, where users can specify one or more rules for placing game objects based on three space syntax characteristics: connectivity, openness, and visual complexity.

A generic rule is as follows:

```
{ "Game Object": [string TypeID, string GroupID, int Priority, int Cardinality, int Openness, int Visual Complexity, int Connectivity, int Precision, int Distance, int DistancePriority, int DistanceID] }
```

The variable "TypeID" holds a reference to the game object being used (e.g., it could be an avatar), which can be instantiated from the "Resources" folder in Unity. "GroupID" refers to the group a game object is part of (e.g., characters).

Priority refers to what rule in the set of rules has priority (lower = higher priority). Cardinality refers to how many of this game object should spawn in the Unity scene. Using the tool QGIS [10] a connectivity graph is generated and using Grasshopper [27] visibility and openness data are generated. This produces values for openness, visual complexity, and connectivity, which are then encoded into an image in terms of RGB values (red = openness, green = visual complexity, blue = connectivity), which holds an integer value between 0 (low) and 255 (high). The values in the image are used by the algorithm to determine areas of low/high values for each space syntax attribute. Precision is an integer value that indicates that the specified space syntax integer must be within $\pm$ the precision value. For example, if the desired visual complexity value is 43 with precision 20, then the total range for valid visual complexity values are (23, 63). Distance refers to the distance in metres that an object needs to be from another object defined by its integer ID (distanceID). These rules are processed using a greedy algorithm with the highest priority rule being processed first. The rule finds a set of locations that satisfies the space syntax constraints and randomly chooses a position from these acceptable points. This means that different runs of the algorithm will often generate different positions for the game elements. This plugin was integrated into Story CreatAR and used to place story elements.

3.3 AdventureAR

AdventureAR is a *site-agnostic* game based loosely off the old Atari game called *Adventure* [19] (Figure 3.1). During this experience, a user walks in a building-scale environment searching for keys and chests. Keys are acquired by walking into them and each key opens a specific chest. The objective of the game is to open the chest that holds a golden chalice and return to where the game started while avoiding the monster. Chests were placed in areas with high connectivity, so there are many ways to get to them. Keys were placed in areas with low connectivity and high openness, so the locations were challenging to arrive at, but the object was easy to find once the user reached the general area. Different rules were tested, but these ones seemed to work best for the game. Monsters roamed the area unreliant on space syntax characteristics.

Figure 3.1: Left: a virtual chest. Middle: a virtual key. Right: a monster roams throughout the play area in the Mona Campbell building.

3.4 ScavengAR

ScavengAR is a *site-specific* scavenger hunt game shown in Figure 3.2. ScavengAR was deployed to two different Dalhousie building locations (Mona Campbell and Goldberg) using the same rulesets. ScavengAR in the Mona Campbell building was used by new Graphics and Experiential Media (GEM) LAB graduate students to learn about the different rooms and tools available in the space. For example, in one room there is a 3D printer available. Similarly, ScavengAR in the Goldberg building was used by new first-year students to understand the amenities available to them on the first floor of the Goldberg building. For example, one location shows a CS Help Desk.

As ScavengAR contained content pertinent to its location, some object's positions were constrained first by a general region (e.g., a room or corridor), and then we looked for the best suited space syntax values. For example, virtual 3D question marks were first constrained by their general location and then were placed based on highest visibility and connectivity. In contrast, virtual 3D coins were placed throughout the building based on low values of each openness, visual complexity, and connectivity.

3.4.1 Design and Implementation

I used a *10 plus 10 approach* [1] for the design of the interface for reading messages and for guiding the user to the next location. In the 10 plus 10 approach, I first considered 10 ideas for both aspects. For example, for guiding the user there could be a trail, points leading to the next location, a compass pointing to the next location, etc.. This lead to two choices for the game: for reading notes there is a 3D question mark that when selected is replaced by a note and for directing the user to a new location there is a dynamic arrow that points directly to the next location. A storyboard was

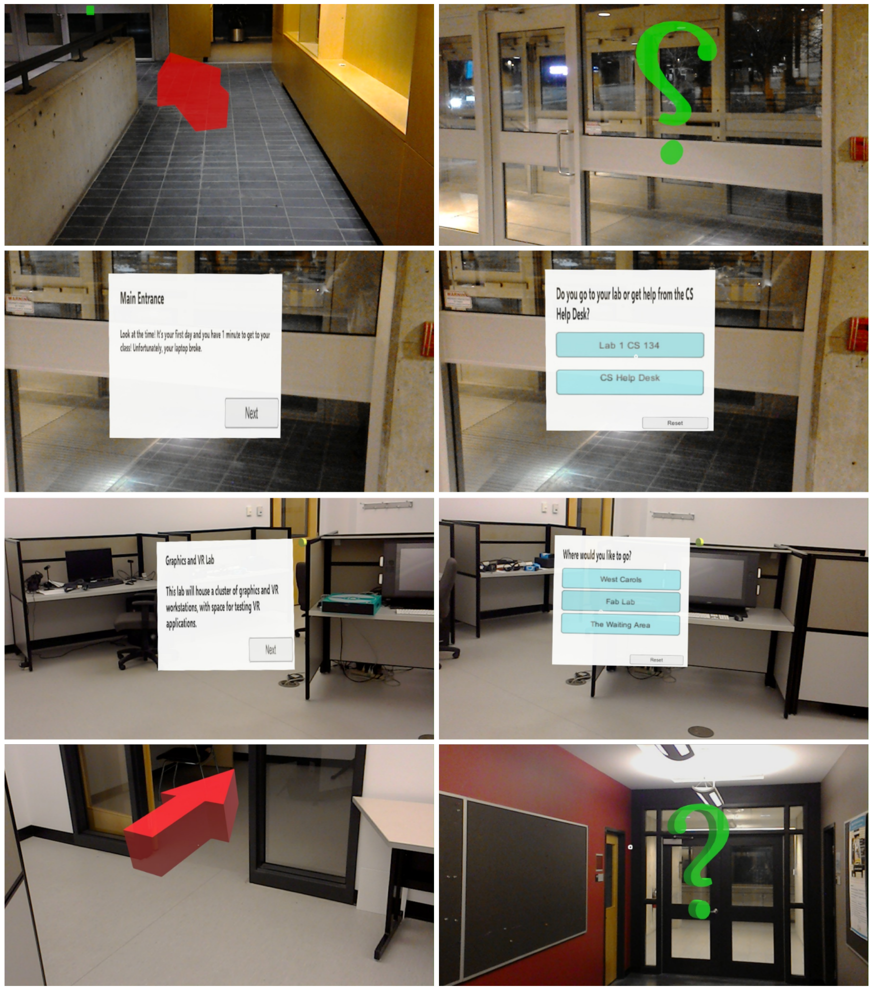


Figure 3.2: ScavengAR played in the Goldberg and Mona Campbell Buildings. An arrow guides the user to a question mark, which is replaced by an informative note and a choice of where to go next.

created to show the flow of a user playing the game. In ScavengAR, the user finds 3D question marks using a dynamic arrow as a guide. The user can click on the question marks using the HoloLens select gesture, which is replaced by a note. The note provides a description of the location and allows the user to choose out of a set of predefined options where to go next. Coins can be acquired using the select gesture. When a coin is selected, a counter is incremented and shown in a heads-up-display. However, the coins do not impact the game experience in any other ways.

3.4.2 Lessons learned from creating ScavengAR

Lesson 1: Consider the form the locative information should be viewed (or not viewed).

The locative information could be shown through a virtual character/object, text displayed on the screen, events that unfold, and audio being played. In ScavengAR the locative information was shown textually on a virtual note.

Lesson 2: Consider how to guide the users from one location to the next.

I followed a 10 plus 10 approach for designing how to lead the user to the next location of interest. I opted for a dynamic arrow that is ray-casted on top of the ground and guides the user directly to the next point of interest. Alternatively, this could have been an open exploration where users can stumble upon the locative information.

Lesson 3: Demonstrate to potential users and iterate on game design based on user feedback.

During the *Women in Tech* day at Dalhousie, this game was tested by female high school students. We have informal impressions that the students enjoyed the game and its interactivity. Moreover, feedback received in the demonstration allowed for further refinement of the game (e.g., including wall occlusion so users can not see into other rooms before they are inside).

3.5 Summary

I described preliminary work conducted prior to Story CreatAR. This involved two proof-of-concept games called ScavengAR and Adventure AR, which had game elements placed by a space syntax rule-based algorithm. I created ScavengAR in my undergraduate directed studies course and derived several important design lessons from it.

Chapter 4

Story CreatAR Design Process

4.1 Introduction

Preliminary Work details two proof-of-concept immersive AR games for placing game elements using spatial analysis techniques. We opportunistically migrated to using spatial analysis techniques for creating immersive AR *stories* in response to the Snap Creative Challenge: "Reimagine The Future of Storytelling with Augmented Reality" [17]. The content of this chapter is described elsewhere [123]:

> A. Singh et al., "Story CreatAR: a Toolkit for Spatially-Adaptive Augmented Reality Storytelling," 2021 IEEE Virtual Reality and 3D User Interfaces (VR), 2021, pp. 713–722, doi: 10.1109/VR50410.2021.00098.

This chapter expands on the material in the reference by providing additional details and reflection, particularly on the design activities. From the start of the design of Story CreatAR until the Snap Creative Challenge (four months) we met bi-monthly with our Microsoft Research mentor where we discussed progress and ideas for next steps. They introduced us to the Microsoft RocketBox avatars, which heavily influenced the nature of the stories Story CreatAR supports (avatar-driven stories). In my honours project, me and other researchers followed several design activities resulting in a prototype to motivate the design of Story CreatAR (found in Section 4.2.1). The medium-fidelity prototype was developed during my masters program. We created Story CreatAR during two user-centered design phases. Phase One involved design activities such as brainstorming, storyboarding, and user interviews, which lead to a medium fidelity prototype and later a proof-of-concept story implementation called *The Lost Child*. Phase Two involved utilizing feedback and lessons learned from The Lost Child implementation, as well as, adding new features in response to our authors' stories and feedback. The two design phases lead to Story CreatAR, described in Chapter 5.

4.2 Methodology

4.2.1 Phase 1

Brainstorming

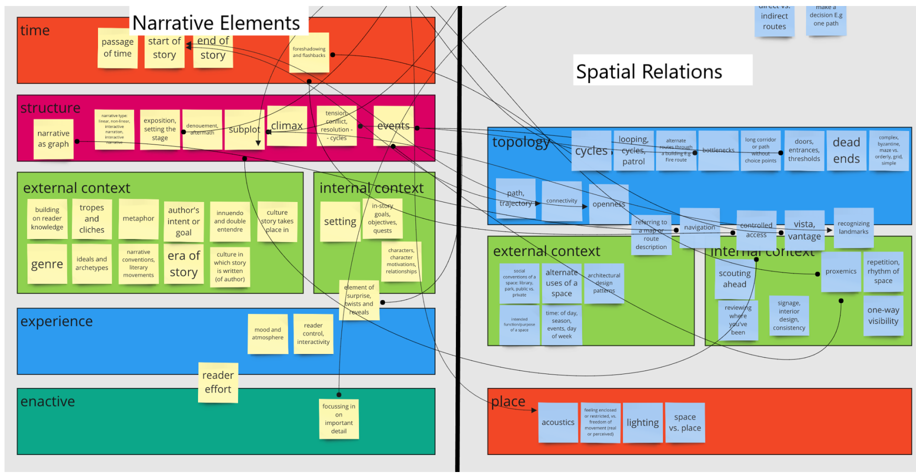


Figure 4.1: Left: possible narrative elements organized into different sections. Right: possible spatial relations. Arrows illustrate potential mappings between the two.

There has been research into some potential mappings between narrative elements (e.g., climax) and the spatial configurations (e.g., bottlenecks) [54, 62], but there is not a comprehensive set of these mappings. Therefore, early in the design process, we brainstormed potential relationships between narrative elements and spatial relations. In a group with me, other lab members, and two locative media artists, we brainstormed possible narrative elements (e.g., sounds, tension, type of narrative, etc.) and spatial aspects (e.g., lighting, bottlenecks, vantage points, etc.). This list was a result of prior knowledge and a brief literature review. From there we derived possible mappings between these two sets, which were iterated on during the early design work. Some possible mappings are shown in Figure 4.1. This figure shows a culmination of the mapping activity and a more detailed version can be easily found at this Miro Board. Miro [11] is an online whiteboard for visual collaboration. It allowed us to have a large canvas to visualize our mappings. I will go through several example mappings used in Story CreatAR to show their usefulness.

- Narrative components/scenes can be located in specific rooms and spaces.

- Character dialogue can be triggered by proxemics and F-formations.
- Elements of surprise can be mapped to low visual complexity areas.
- Start of a story can be mapped to an open area.

Storyboarding

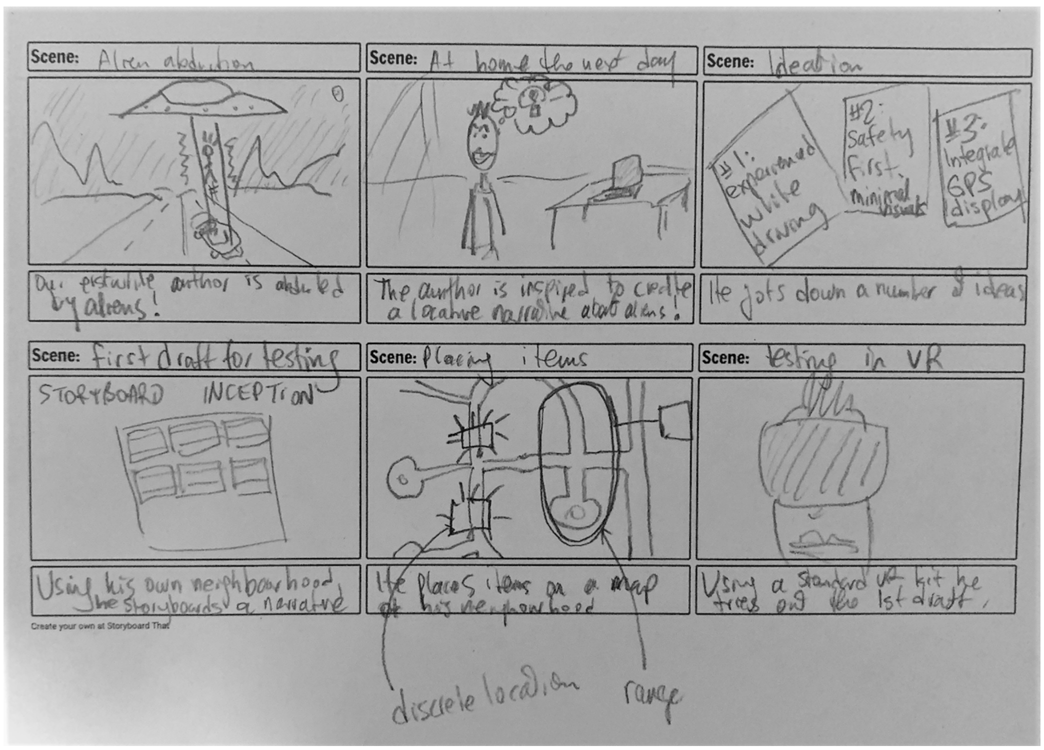


Figure 4.2: A storyboard considering how an author conceives (ideation), implements (first draft for testing), and tests their story (testing in VR).

Several members in the project created individual storyboards illustrating potential use cases of an author using our tool. The storyboard activity was used to find issues that authors may experience and discover missing or unnecessary features. First, we considered several questions including the authoring process, how and when an author will test their narrative, what spatial relations an author desires, and how much control an author should have over how a viewer experiences the narrative. I created a storyboard for a possible interface an author may use (Figure 4.3). In this design I provided authors with rich story content and customization abilities. However, this storyboard lacked a means for authors to perform mappings between

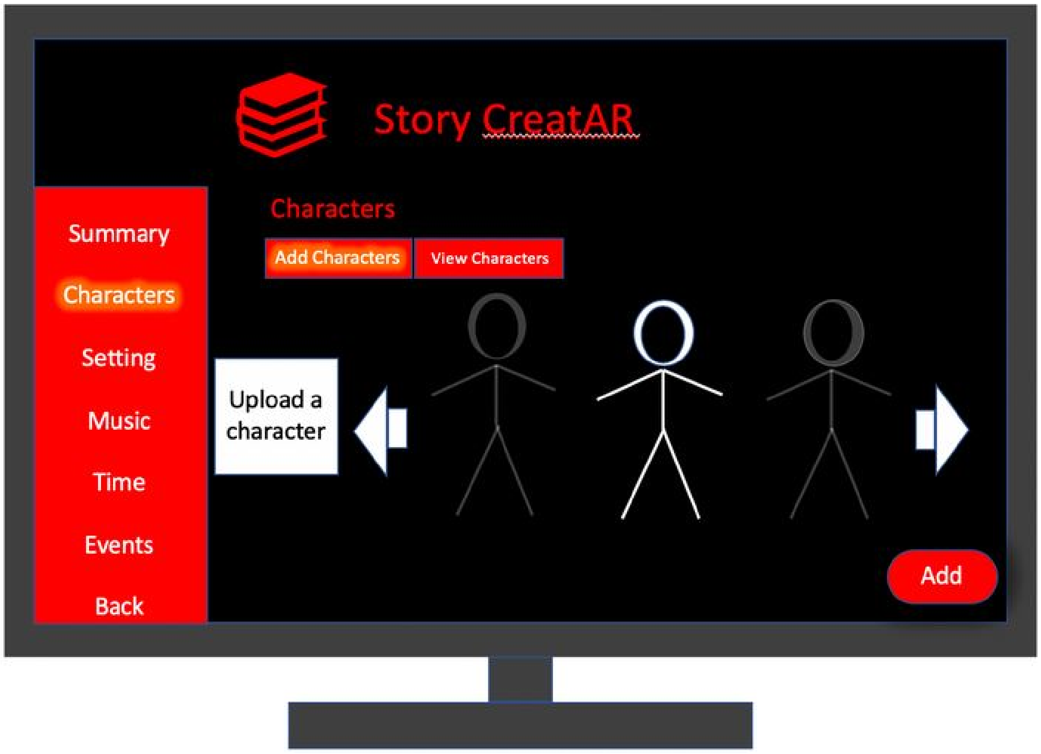


Figure 4.3: A potential interface for an author creating a story.

narrative elements and spatial relations, a way to test the placement, and a way to deploy to the HoloLens 2. Once all storyboards were realized, each storyboard was walked through and we derived several key insights for the design of Story CreatAR.

- An author should be able to choose the mappings between narrative elements and spatial relations. This is motivated by the storyboard shown in Figure 4.5, which shows that authors may specify correspondences between narrative elements and spatial relations.

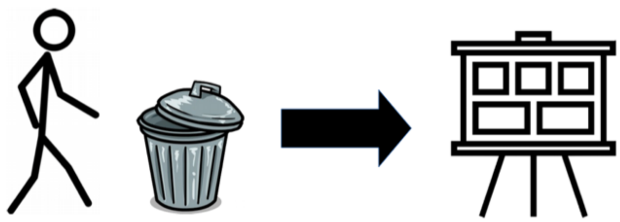
- An author should be able to test the mappings (and story content) using VR. This is shown in Figure 4.2 as after an author places items, they will test the experience in VR.

- Deleting objects or mappings should not break the experience as it is an expected part of the authoring process. This was derived by Figure 4.4 and Figure 4.3, which indicates that part of the authoring process involves modifying story elements.

Key Items: Adding an element, where will it go?

Scene 4: Deleting or modifying a narrative element from the story

An author needs to be able to delete or modify a narrative element. The author should also be able to see how the deletion or modification will impact the story as a whole.



Key Items: Deleting an Item, How does the story get affected, Narrative element dependencies.

Figure 4.4: An author modifying story elements.

- An author should be able to manually place an object at a precise location. This is shown in Figure 4.2, where an author chooses where to place story elements on a map.

Expert Interviews

We conducted interviews with two expanded media practitioners and two locative media Nova Scotia College of Art and Design (NSCAD) students to identify the needs of our application as we were planning to work with the students during the implementation of Story CreatAR (however they had other commitments). These interviews were recorded and executed in a semi-structured fashion. Interview questions ranged from previous locative media experiences to suggestions for features of a locative media tool. The full list of prepared interview questions can be found in Appendix A.

A locative media practitioner, and a member of the Narratives in Space and Time society[1] emphasized the need to limit the amount of information provided to the

[1] http://www.narrativesinspaceandtime.ca/

viewer and to minimize text. Therefore, Story CreatAR provides spatialized audio in addition to audible conversations rather than textual pop-ups. They reinforced the importance of our brainstorming activity as they suggested a spatial-narrative mapping (rooms can be associated with sub-topics in the story). A professor of media arts at NSCAD University also emphasized the importance of minimizing text to maintain engagement. Since the immersive AR/VR experience is already highly visual it is better to use audible sounds instead of text to not overwhelm or distract the user. The NSCAD students discussed their previous locative media experiences and concepts they may use for their story, which are supported by Story CreatAR: audio cues to direct the user's attention, having triggers based on proxemics, and considering who the audience would be.

Personas

We considered possible use cases for the tool and derived three primary users based on these use cases: someone that is an expert with locative narratives; someone with expertise using the tool; and end users (people experiencing the story). Someone with expertise creating locative narratives would not require organizing and structuring help to create their story. Someone with expertise with the tool would be a frequent user of Story CreatAR and would not require additional guidelines to help navigate it. End users would be viewers experiencing the story through the HoloLens 2 and may require help to use the HoloLens 2. One special case of end users is when the story should be experienced at multiple locations. For new locations the end user would require a floorplan and the spatial analysis output for that floorplan. We imagine that the locations would have a *site-administrator* who is responsible for making any modifications to the story (e.g., story element positions, timing of events, etc.) based on the floorplan for their site. The end user may reuse the rules from the original author and make adjustments as necessary.

We also brainstormed a set of tasks for an author using the tool. We acknowledge the limitations of this process as it was not validated with target users and not derived from user research. However, they provide ideas of tasks we wanted our tool to offer. The work generated ideas that we more formally evaluate later. Some possible tasks that we later implemented in Story CreatAR that a user may want to perform are:

- creating a story,
- naming a story and inputting the author,
- choosing a point of view,
- creating story events,
- adding characters,
- adding audio,
- adding objects,
- performing mappings between the virtual and physical world, and
- testing the story in VR.

These tasks reinforce the ideas of supporting author-specified mappings and testing those mappings in the medium (VR) that were suggested from our storyboarding activity. An important task for authors using Story CreatAR is creating the mappings between the content and the spatial configuration. We expect the author to specify the mappings, then check the realization of the mappings in VR, and adjust their placement as necessary. This may be repeated until the mappings are as desired. After playing through an experience, the mappings may change again. Afterwards, a user may want to save the mappings for a specific location, and change to a different location with different mappings. Therefore, mappings should be abstract enough to be reused or repurposed.

Mock Story

A mock story was created to explore what kind of narrative-spatial mappings are desired in a story. The spatial aspect of the mapping was not constrained to space syntax relations, but rather was an open exploration of all spatial relations. The mock story was a variation of the well-known children's tale *The Three Little Pigs*. In this retelling, the message is to support greener energy and to have more energy efficient buildings. Each house can have a staggering difference in energy efficiency.

The wolf represented climate change and he would blow the houses down that are not energy efficient.

We explored what story events we would include (e.g., three pigs build their houses, wolf antagonizes each pig, etc.). These story events included several multimedia aspects (e.g., sounds, animations). Story events might be quite short or could be longer sequences, and might involve only one character, or several characters.

We specifically explored potential narrative-spatial mappings which include:

- The progress on the build of the pig's house mapped to proxemics (Figure 4.6). In other words, the distance from the user to the pig's house. Therefore, proxemic triggers were integrated in Story CreatAR to support event preconditions.

- The pig's houses could be mapped to different rooms or convex spaces in a building. In Story CreatAR we integrate convex analysis to support room-based placement constraints.

- Sound cues can be used to guide the user through the story. In Story CreatAR, we use spatialized audio, which gives a viewer a sense of direction.

The mappings used in The Three Little Pigs story reinforce the mappings derived from our brainstorming activity and suggested by our locative media expert Lilley, which together motivated the ability for authors to specify spatial-narrative mappings in Story CreatAR. One important question that arises with this example is: when should we use an existing ruleset, and when do we actually need to create new rules/relationships to simplify the authoring process? To do this we should track desired new rules by authors using our tool and look for ways to support these rules.

Medium-Fidelity Prototype

Through the design activities we derived key features and functionality that resulted in a medium-fi prototype of our authoring interface. The medium-fi prototype was designed in PowerPoint (using page link functionality to create buttons). The prototype provided the following functionality:

- create and edit stories,

- add story components (text, characters, music, events) with the ability to upload their own. Events have a numerical order index and an amount it is repeated,

- the story can be broken up into chapters, where each chapter represents a set of events,

- the author can upload their own floorplan and associated space syntax analysis information. Then, they can learn how to do the calibration,

- given a floorplan, authors can associate story components they specified previously with spatial characteristics of the floorplan (e.g., high openness). The screen for mapping is shown in Figure 4.7. These mappings can be directly viewed in VR, and

- the author can view a story and deploy it to a VR headset.

We had other lab members walk through the medium-fi prototype, which resulted in feedback that influenced Story CreatAR. Some feedback regarded user interface improvements: "music" should be renamed to "audio" and some text should be changed to icons to make it easier for a user of the system to understand. Other feedback regarded functionality improvements that were implemented in Story CreatAR:

- the ability to attach audio to characters or events (e.g., characters talking in a conversation),

- assign characters a spatial attribute (placing characters in spatially appropriate locations),

- have looping audio (background noise or an audio file that should be played repeatedly until interrupted),

- designate and label rooms (to apply room constraints),

- view the outcome of the mappings in the interface (quicker to test on a computer screen than deploying to VR),

- create and assign spatial rules to groups as opposed to one-by-one, which can become tedious for many story elements,

- remove the calibration component as it is not required for VR (however it is required for AR to align the physical world with the virtual world), and
- provide default maps the user can select from (as they may not have or know their target floorplan).

Additional suggestions not implemented in Story CreatAR include: the ability to designate regions as out-of-bounds, assign likelihoods for events to occur, and potentially represent the mapping interface as a state machine. We did not implement the out-of-bounds regions and event likelihoods due to time constraints and prioritization of features. We did look into different ways to represent the mapping screen, however, we did not represent it as a state machine. Instead we provide the placement on a visual map for our authors.

Snap Challenge Panel Evaluation

The medium-fi prototype was used to motivate features in a proof-of-concept story called *The Lost Child*, which was created for the Snap Creative Challenge [17] in consultation with one of our authors. The narrative is centered around a distraught father trying to find his missing son, shown in VR in Figure 4.8. Due to the story being created at the same time as Story CreatAR, this story was implemented by another student directly in Unity as a proof-of-concept for what Story CreatAR could produce. Story elements were placed based on spatial rules and conversations used spatialized dialogue and could be interacted with through proxemic triggers.

This story motivated the design of Story CreatAR in several ways. The story focuses on proxemic triggered dialogue, which was motivated by the brainstorming activity mappings and by our mock story of The Three Little Pigs. For example, a viewer in VR could go up to a group of characters and they would talk to the viewer. Therefore, Story CreatAR required the ability to define proxemic rules, the ability to attach dialogue to a character, and the ability to play spatialized sounds. Background characters were required to converse with one another, which were arranged in a circular F-formation.

As part of the Snap Creative Challenge [17] hosted by Snap Inc. we presented our design process, medium-fidelity prototype, and proof-of-concept story to an expert panel: a Lead Research Scientist at Snap Inc; a Project Research and Development Engineer at the BBC; and a Senior Researcher at Microsoft Research. The experts provided positive feedback regarding the voice acting and the flow of the experience. However, they held some reservations on how effectively authors would understand and use the spatial rules provided by the tool. Therefore, we created higher-level spatial qualities called *attributes* to hide the lower level complexities involved in spatial analysis. We provide a default collection of these attributes for authors to use and the ability for authors to create their own.

4.2.2 Phase Two

During Phase Two, we collaborated heavily with three authors while Story CreatAR was developed. All authors were cinema and media studies students at Dalhousie doing a directed studies course. The authors (expert users of our tool) were involved with the design of Story CreatAR, which is a method employed when designing other locative media experiences [25, 68]. This occurred over the course of four months during which we developed Story CreatAR and they created their narratives. Therefore, Story CreatAR is a direct result of author's feedback, narrative requirements, and suggestions they made throughout our meetings.

We held weekly sessions over four months with the authors and we:

- *discussed spatial analysis concepts Story CreatAR may use*: so the authors are familiar with the concepts employed in the tool and to inform design decisions for Story CreatAR (e.g., find out what is confusing to authors and what features seem useful to authors),

- *presented related new media and HCI literature*: so the authors are aware of current state of the art narrative creations and they are more apt to design something novel.

- *demoed Story CreatAR features and workflow*: to update the authors on the progress of Story CreatAR and get their feedback so we could reflect on it.

- *presented stories implemented by Story CreatAR*: to show authors its capabilities, and

- *discussed feasibility of their story ideas*: to give them expectations of what can be made with Story CreatAR. For example, when we decide to implement the story, the more custom features may not get implemented (e.g., being able to flip through a book with specific text and images), however, we still try to capture the general essence of the story.

We encountered a challenge of having shared knowledge about the capabilities of the target device (either Oculus Quest for testing or HoloLens 2 for deployment) between the authors and developers. These challenges included how close a user can get to virtual objects, capabilities of the medium (e.g., ability to have an inventory system), what interactions are available, how/where HoloLens tracks viewer position (i.e., HoloLens position is tracked at the user's nose), field of view of the HoloLens, whether physical furniture is accounted for in the virtual world and spatial analysis, how real-world lighting effects virtual objects, possible point of view in stories, and viewer's ability to input text. We did discuss these misconceptions with our collaborating authors, but most authors using our tool may not have ready access to these resources. That means other authors would still have to overcome these misconceptions, potentially without having an expert to ask their questions to, which could translate into a much more challenging experience as this information may be difficult to find online. We asked authors to be creative with their stories and not be constrained by the features of Story CreatAR.

We followed three distinct approaches (developer, graph, and author) for creating an initial implementation of our three collaborating authors stories. Each approach provided an exploration on how each method worked and allowed us to identify required features for Story CreatAR, which are discussed in more detail in the following section. For one author, we followed a *developer approach* where a developer used the author's story script to implement their story using Story CreatAR and added additional story specific functionality. The developer approach showed what Story CreatAR could offer as the developer could implement additional features to polish the story. For the second author, we followed a *graph-based approach* where a developer and an author collaborated to create a graph representation of the author's story script. We believed a graph representation may be better for representing complex or nonlinear narratives. As one story fit this category, we explored the pros and cons of representing their story as a graph. We also expected this to ease the translation of the story to Story CreatAR. For the third author, we followed an *author-driven approach* where an author directly used Story CreatAR. We explored how a nontechnical author used the system, specifically what they could achieve easily and what difficulties they faced. These three approaches motivated the structured evaluation of Story CreatAR discussed in Chapter 6.

4.3 Case Studies

In our case studies we implemented our three authors stories in three different ways. We identified our authors needs based on what aspects of the story that we were not able to implement in Story CreatAR, but were important components to their stories. In the following sections we refer to our authors using pseudonyms.

4.3.1 Tyson's Peak

Anna authored *Tyson's Peak*. Anna has limited technical expertise, but has won several creative writing prizes and is a cinema and media studies graduate. Tyson's Peak is about a group of friends trapped in a cabin on a ski trip. The story takes a devious twist when one friend is murdered with poison. The player is able to eavesdrop on characters to understand the plot. Anna was focused on engaging participants in the narrative, "we're all focusing on presence – we want participant to be part of the narrative".

A developer implemented the first seven minutes of this story as a more advanced proof-of-concept (i.e., the story consisted of timed events where certain scenes happened under a set duration). During this process, the student used Story CreatAR to place objects and avatars by space syntax analysis. The spatial rules the student used were derived from the script. They followed room-based rules which were specified by openness, connectivity, and proximity to other rooms. They also constrained conversation placement within a room, areas with different values of visual integration and openness, and distance to other conversations. Lastly, they constrained conversations to play their dialogue by the player's distance to the conversation. Then, the student acquired and imported 3D assets specified in the story, imported the desired avatars chosen by the author, and arranged voice recordings for avatar dialogue lines.

The functionality for creating conversations was implemented in parallel to the implementation of this story. The result of the developer approach is shown in Figure 4.9.

Influence on Story CreatAR

This story emphasizes some of the desired features from The Lost Child such as arranging avatars in a conversation, using spatialized and looping dialogue (e.g., for background conversation noise), being able to organize (group) assets, and assign animations to avatars (e.g., talking animations). Anna explains why she uses looping dialogue in the story: "this was a choice – and based on experience of video games (Pokemon and Zelda) which use this to cue the participant to move on – and choice to limit the repetitions to five minutes keep it from getting too annoying". This story resulted in a new feature for Story CreatAR: the ability to make avatars arrange and talk in a conversation. Notably, this resulted in the need to place not only objects, avatars, and sounds by spatial analysis, but also conversations as avatars may come and go from a conversation during the game play. Tyson's Peak reinforced the ideas of The Lost Child demonstration, mock story (The Three Little Pigs), and the brainstorming session, which motivated the narrative-spatial association feature. Since there were a lot of assets in the story, this created a need to organize the assets in the story (e.g., providing a label/group for all characters). Furthermore, in order to progress the story, this case study identified a need to support avatars moving to different conversations at different times in the story. During the development of this story, timer (specifying a time to wait) and traversal (moving an avatar to location B) events were created.

4.3.2 Standville Museum

Eric authored *Standville Museum*. Eric is a novice user of technology, but an experienced book writer. Standville Museum is about a detective at Standville Museum who solves clues and riddles to find his missing son. Eric, with aid from his supervisor, Amy, implemented his story using the Story CreatAR interface. Due to COVID-19 restrictions, we met remotely, where Eric/Amy used Chrome Remote Desktop to control my screen because Story CreatAR was available only in the Unity Editor and we did not want to require the authors to download Unity. Story CreatAR is only available in the Unity Editor as we do not want to lose the inherit functionality associated with the editor (e.g., customizing assets, modifying placement within a Unity Scene, and deploying to VR/AR). We did not want users to download Unity as it is a complex process for downloading the project via GitHub, configuring the software development kits and integrated development environments, and Unity itself is very resource intensive. Eric's intention was to create the initial placement for objects in one chapter of his story. Eric's process in Story CreatAR follows.

1. Eric inputted a unique author and title pair.
2. Eric added story elements (avatars and objects) and later renamed them using the *Edit Story Element* feature.
3. Eric began specifying placement rules without adding any *Groups* despite the *Groups* feature being on the same window as the *Add Story Elements* feature.
4. Then, Eric added *Default Attributes* to his story elements to constrain their placement. For example, the detective was associated with the *Open Area* attribute and the clues were associated with a *Hidden* attribute. Eric did **not** *Create a New Attribute*, which uses low level space syntax characteristics.
5. Eric selected *Reapply Rules* numerous times to view different placements of the story elements.
6. Eric also viewed his placement in the 3D preview and made minor adjustments to his placement. However, I aided Eric to make these adjustments as he was a first-time user of Unity 3D.

Influence on Story CreatAR

Standville Museum is heavily described on a room-by-room basis, requiring many story elements to be placed within the same room. To meet this requirement, we utilized a room-based analysis tool known as AFPlan [136] to allow Eric to place objects within a room. Eric also desired more precise placement for objects than offered by the tool such as "On wall" or "Against wall", which could be accomplished by other space syntax analysis qualities (e.g., minimum radial length) or by integrating other tools such as FLARE [55]. More precise placement for objects, the ability to make minor adjustments to placement within Story CreatAR, and providing images for third party content was not implemented due to time constraints. Other suggestions noted during Eric's experience were to add visual icons of the objects (instead of a purely textual list), moving objects via a drag and drop interface, and showing which story elements are part of what group in the placement screen. Notably, Eric had an overall positive experience using Story CreatAR as he states, "I liked that we don't have to worry about going around the map and placing everything".

4.3.3 Spill

Ryan authored *Spill*. Ryan is our most technical author with a year of computer science study and is an experienced video game player. In Spill, the player is met with the party's devious host, Miss Fokthipur. The player can eavesdrop on partygoers secrets to learn the keyword to escape the party. Ryan wants the experience to happen and the player be part of it, but not the focus of the experience: "we want to tell the story with the player, not in spite of the player". However, if in the story experience the player does not conform to social expectations, they may be forced to leave the party early. Ryan did not like the use of looping dialogue as he wanted to make player interactivity a priority: "for an experienced video game player, this [looping dialogue] may be a little tough because it doesn't rely on player interactivity as much – in Pokemon, etc., you need to hit an X to get them to talk". Ryan worked with a Dalhousie Computer Science professor to create graph representations of his story, one of which is shown in Figure 4.10. This helped visualize the flow of the story, and was useful for organizing content. This graph can be translated to Story CreatAR. For instance, Ryan has a node called "Special Convo", which the player may eavesdrop on to hear the keyword. In Story CreatAR, Ryan may create a conversation node called "Special Convo", which when the player is in eavesdropping distance a keyword is announced. We expect graphs to ease the translation of a story to Story CreatAR, but we leave this to be further explored in Chapter 6.

4.3.4 Summary

We created Story CreatAR using a two phase user-centered design process. The first phase involved design activities to better understand the needs of our users and features that would be crucial for our application (e.g., an interface for authors to specify mappings between spatial relations and narratives elements, a way to test those mappings, and a method for deployment on-site). The second phase involved an iterative design process between sharing Story CreatAR development progress with authors and reflecting on authors' stories as they were being developed to better suit their needs. Lastly, we discuss several case studies from our authors' stories and how each influenced Story CreatAR. We identified the authors needs based on the story script itself, discussion with the authors, and the implementation of authors stories in our case studies.

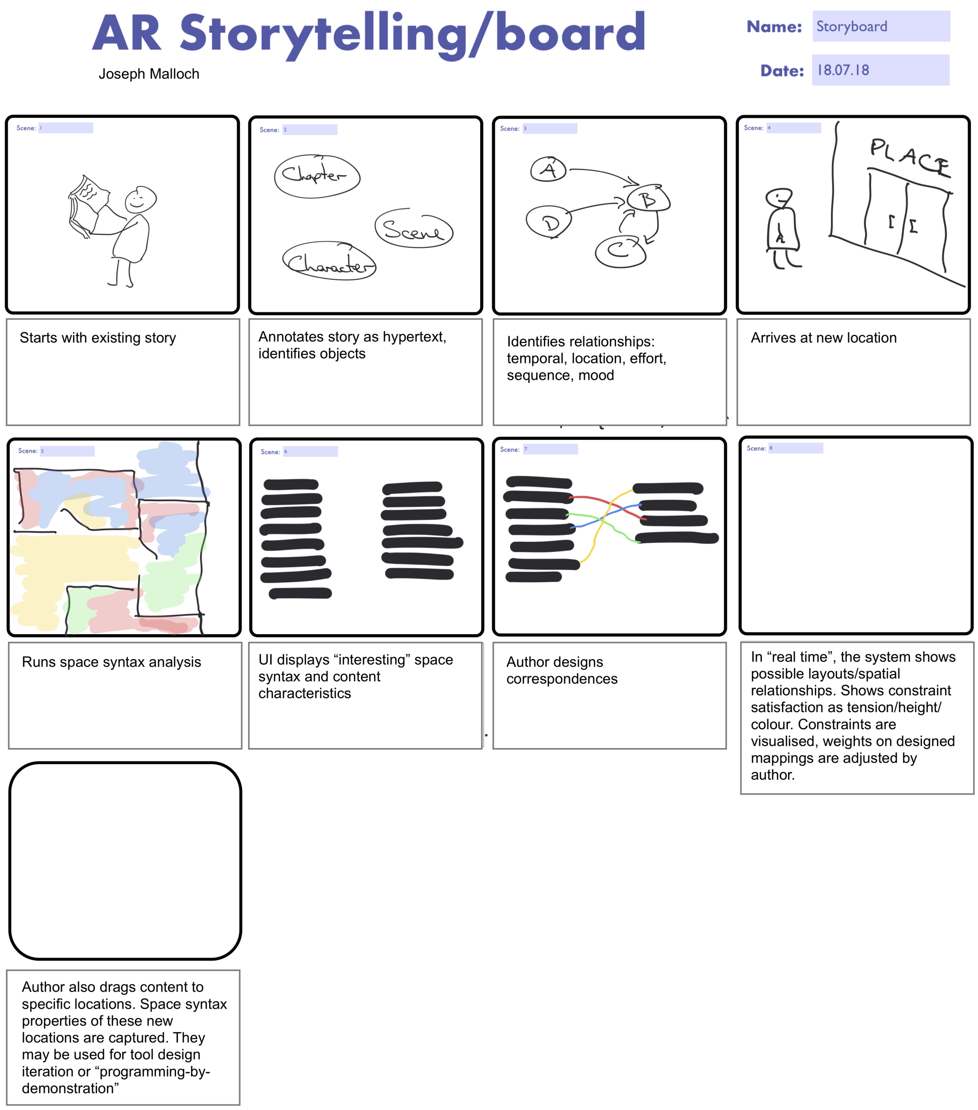


Figure 4.5: Storyboard showing author-defined spatial and narrative mappings.

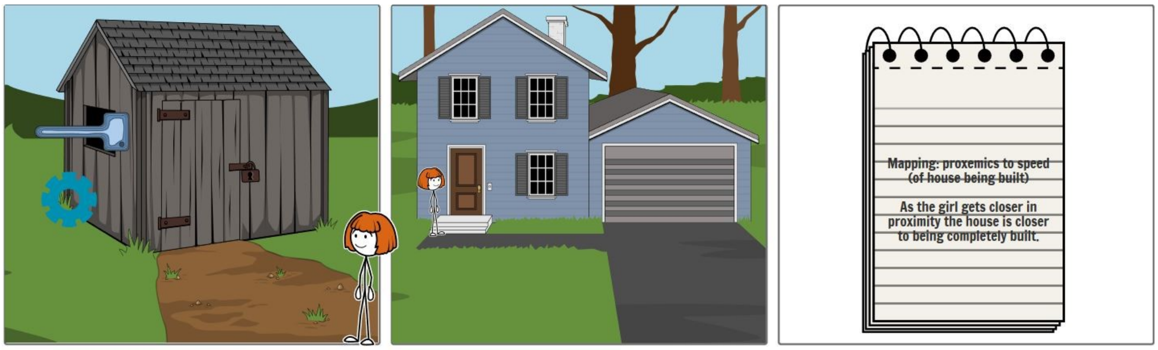


Figure 4.6: The proximity of a viewer is mapped to the outcome of the house being built.

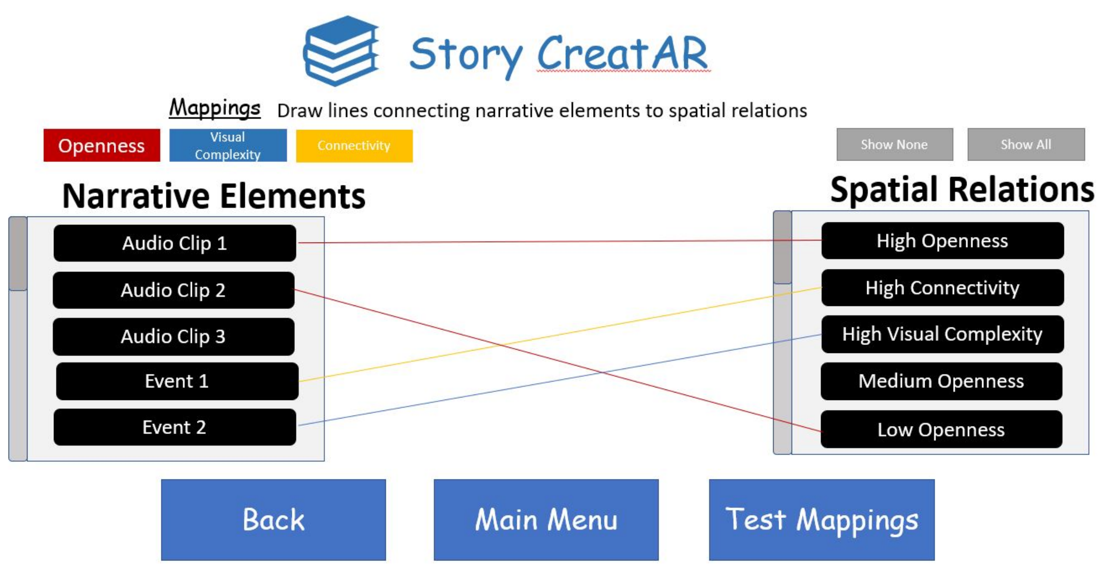


Figure 4.7: The screen where authors can associate narrative elements with spatial relations.

Figure 4.8: The father (right) of the lost child is in distress talking to a group of people.

Figure 4.9: This shows a scene in Tyson's Peak created by a developer. Avatars are gathered in conversations and ski cabin furniture is placed in the main area.

Figure 4.10: Ryan colorfully illustrates his story, with sub-story topics connected by player actions.

Chapter 5

Story CreatAR System Design

5.1 Introduction

I created Story CreatAR with help from other students. I designed and implemented the user interface, integrated the key features of the tool that other students created, designed the flow of Story CreatAR, and provided guidance regarding how features should be implemented. Specifically, other students were responsible for rigging and importing avatars from the Rocketbox Avatars [93], exposing the depthMapX [43] command line interface (CLI) to Story CreatAR, generating room-based analysis comma-separated values (CSV) files, and implementing event functionality (conversations, traversal, timer). In this chapter, I discuss an expected workflow of an author using the tool, the user interface and features available in Story CreatAR, event mechanics, placement rules, and I detail use cases for the tool.

5.2 Workflow

Story CreatAR was developed as a Unity [129] plugin as Unity is a robust game development engine, which facilitates deployment to multiple platforms including AR and VR. Story CreatAR allows authors to create avatar-driven narratives, but requires additional technical support for more complex narratives (e.g., multiple paths that lead to multiple worlds). Story CreatAR follows Aarseth's [21] model for creating ludo-narratives as each dimension in the model (events, objects, locations, and characters) is fundamental to Story CreatAR. Table 5.1 shows how Story CreatAR features map to each dimension of Aarseth's ludo-narrative model. An expected workflow of an author using Story CreatAR is represented in Figure 5.1, however, Story CreatAR does support other workflows.

1. An author creates a story representation (e.g., script, graph, etc.) of their narrative prior to using Story CreatAR. An author uses their story representation

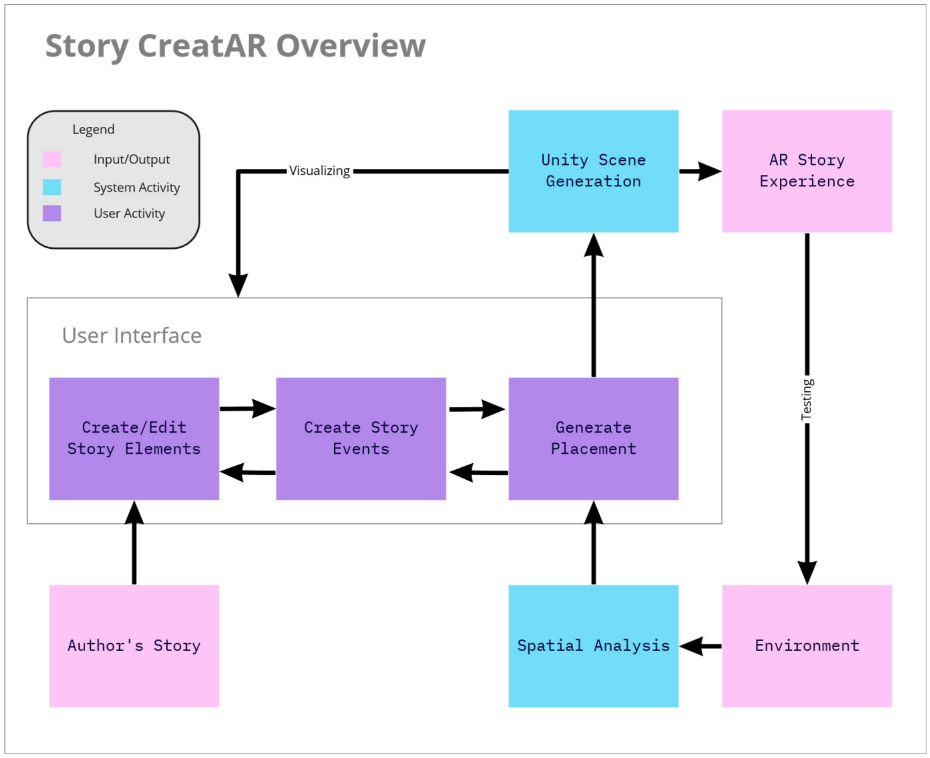


Figure 5.1: Overview of Story CreatAR. An author creates their story, uses the Story CreatAR interface to create their story components, and then deploys the experience to AR.

Ludo-narrative Dimensions	**Related Story CreatAR Feature(s)**
Events	Story CreatAR supports three types of events. Authors are able to specify conversations between avatars, times to wait, and a place to move avatars.
Objects	Story CreatAR supports two types of objects. Authors are able to import spatialized audio and 3D objects to be used in their story.
Locations	Authors using Story CreatAR can specify locations for story components (events, objects, and characters) using spatial rules (convex analysis, space syntax, F-formations)
Characters	Authors have access to characters from the Microsoft Rocketbox Avatar library.

Table 5.1: Story CreatAR's features in relation to Aarseth's [21] ludo-narrative dimensions.

as input to Story CreatAR.

2. The author adds and edits (change name or groups and placement rules associated with the story element, if applicable) story elements (Microsoft Rocketbox Avatars, spatialized sounds, 3D objects).

3. An author uses their story elements to create story events (avatars conversing, avatar traversals, timers).

4. An author defines spatial rules for their story elements and events, and can view placement behaviour for a set rules over one or more sample or target floorplans.

5. After modifying and testing the spatial rules, the author can save the placement into a Unity scene to provide a detailed 3D view on a desktop computer.

6. If desired, the author can return to Story CreatAR and continue modifying the placement or they can manually modify the placement in the scene view.

7. Then, the author can test the placement in the *immersive* virtual environment by deploying to a remote site in VR or on-site in AR.

8. The author can repeat this process from step Two until satisfied with their deployment.

This is one possible workflow of an author using Story CreatAR, however, there are some likely variations to this workflow. We provide an open design for authors to control their workflow, rather than a prescribed workflow that authors must follow in a given order. For instance, an author may use Story CreatAR while simultaneously creating their story, an author may choose to modify their story after testing the immersive AR/VR experience, and authors are able to iterate between step two to seven in any order they choose.

5.3 User Interface (UI)

The hierarchy of the screens in the UI is shown in Figure 5.2. This shows how the different functionalities are connected in Story CreatAR and what background analysis is being used to support them. The black and orange squares represent

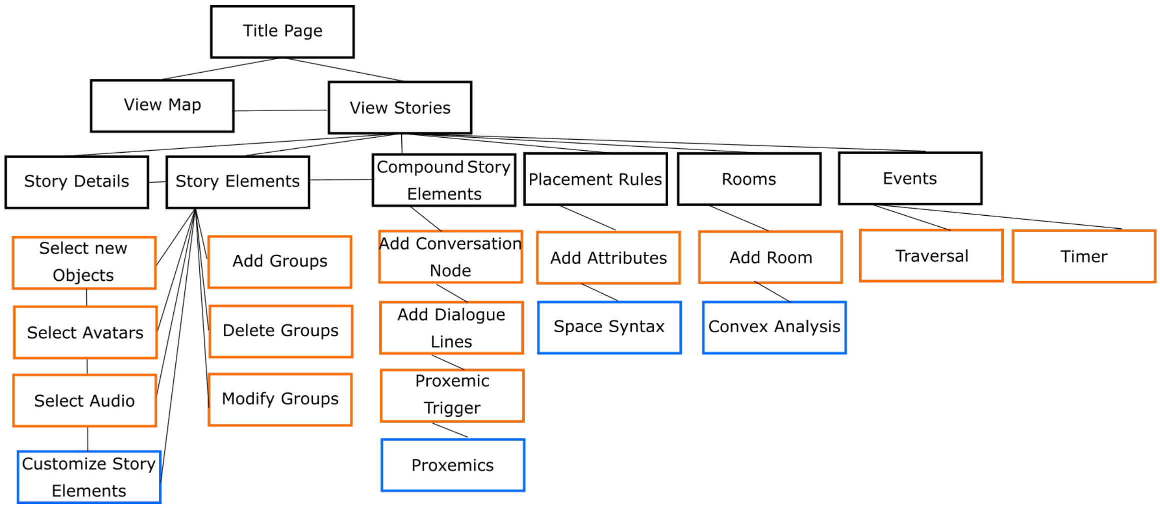


Figure 5.2: Hierarchy of UI Screens

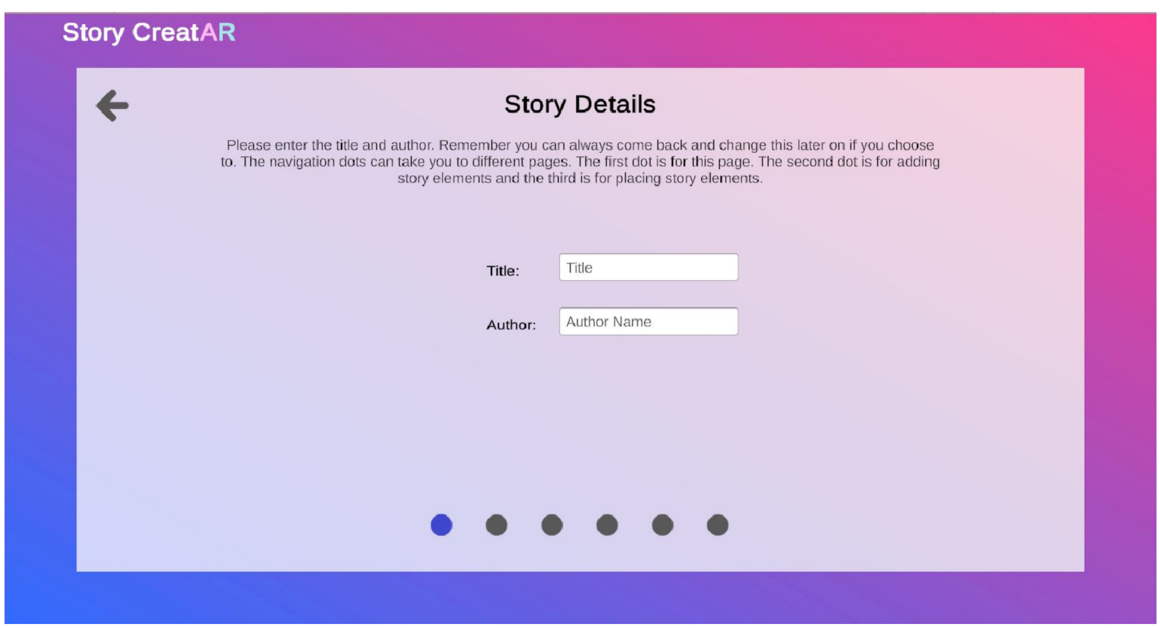


Figure 5.3: Story CreatAR Story Details screen

screens, where the black represents organizational screens and the orange represents features of the tool. The blue squares represent background analysis that is used by the features. There are three main levels to the UI. The second and third main level in the hierarchy (in black) have a dot navigation system at the bottom of the screen so a user can easily navigate between any screens on that level and a back arrow allows the user to go to a previous level (shown in Figure 5.3). If the user is on level three, clicking back will take them to the *View Stories* screen. If the user is on level two, clicking back will take them to the *Title Page*. Users begin at the title screen, at which point they choose to view a map or view stories. When viewing a map, the user is able to add new maps to be used in Story CreatAR. When viewing stories, users can choose to add a new story or edit an existing story. Adding a story takes users to the *Story Details* screen where they can input a unique title and author pair (shown in Figure 5.3). Editing a story takes a user to the *Story Elements* screen, where they are able to add story elements (objects, avatars, audio) or add, delete, and modify groups of story elements. From the *Story Details* or *Story Elements* screen authors are able to go freely between the *Compound Story Elements*, *Rooms*, *Events*, and *Placement Rules* screens.

When authors use the interface in the Unity editor a copy of the author's story creation is saved on their local computer in a json format. For example, on Microsoft Windows the data is saved at "C:/SpaceSyntaxData/Stories.json". This data is loaded when the author returns to the interface so they can save and continue their work. All screens in Story CreatAR can be found in Appendix B.

5.4 Features

5.4.1 Story Content

Story CreatAR allows authors to choose from 115 realistic, rigged human avatars from the *Rocketbox Avatars* [93] ranging between adults, children, and professional workers. Authors can use existing sounds provided by the tool or import custom audio files via a drag and drop interface. Authors can also import 3D objects (e.g., tables or beds) through sites such as **turbosquid** [12] or **free3d** [3] in a Unity compatible format (.fbx, .dae, .dxf, .obj), which can also be imported via a drag and drop interface. We

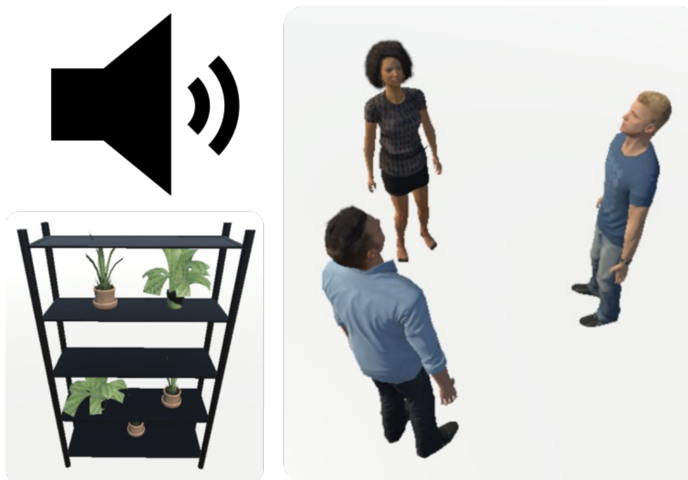


Figure 5.4: Three story elements available in Story CreatAR: 3D sounds, avatars, and props

do not intend to provide default objects for our users: authors will have to source these themselves as they are highly story-specific. In the interface, story content associated with a unique name is known as a *story element*. Story elements can be part of 0-to-many *groups*, where a group can be used for organization or to apply a spatial rule to all group members. However, grouping does not make elements of the same group placed close together. An author can create a group by specifying a name (label) for the group and what story elements are associated with that group. For example, in "The Three Little Pigs" an author may have story elements "Pig1", "Pig2", and "Pig3" and associate these story elements with a group called "Protagonists".

5.4.2 Event Mechanics

Conversation nodes are one type of event that can be triggered when all members of the conversation are present. Therefore, conversations can be activated after another conversation has ended, a certain amount of time has passed, or at the game start. Once active the conversation can be played according to the proxemic rules specified by the author (e.g., a player is facing the conversation causes the avatars in the conversation to turn and speak to the player). Authors can define *conversation nodes* by specifying the following properties:

- unique name (string input),

- type of conversation (intimate, personal, social): how close avatars stand together,
- formation (circle): how avatars arrange themselves,
- initial avatars placed (list of avatar names): avatars in the conversation at game start,
- all avatars involved (list of avatars names): avatars that may be in the conversation at some point during the story,
- out of range audio (background audio file that plays when the player is outside the range of being able to eavesdrop on avatars),
- dialogue players triggered by a player being in eavesdropping distance, in conversing distance, or facing/not facing the conversation.

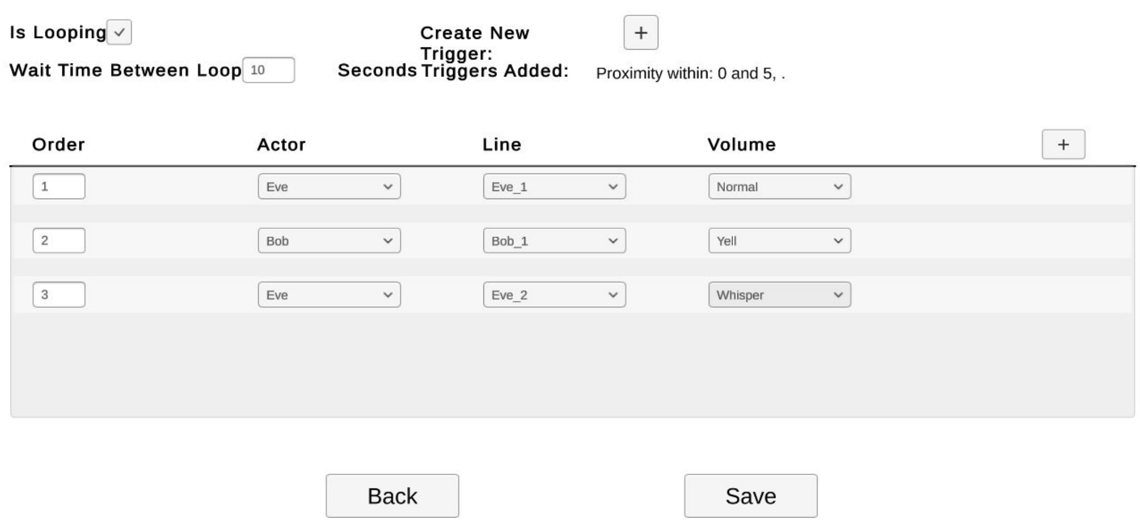


Figure 5.5: Sample input to specify dialogue player properties.

Authors can customize the dialogue players by specifying if they are looping, the time to wait between loops (in seconds), the proxemic trigger associated with the dialogue, and a list of voice lines. A voice line has an index representing the order it is played in, an actor (avatar) to speak the voice lines, an audio file, and the volume (whisper, normal, yelling) of the audio. The proxemic trigger can be based on distance or orientation. For the distance trigger an author must specify a min

(0 – 4 meters) and max (1 – 5 meters) distance through a dropdown selection. The dialogue would only play when the viewer is within that distance. We use distance ranges rather than user-specified distances to help constrain what is reasonable input. For example, if the distance is less than 1 metre, it is likely we will not be able to see all avatars in the conversation. For the orientation trigger an author must choose from one of two dropdown options: is facing (within 30° of the target) or not facing. Similarly, we constrain the orientation trigger to facing/not facing rather than user-specified integer values as this helps authors by constraining the plausible options. For example, Figure 5.5 has a conversation that is looping with a 10 second wait time between loops. The conversation is triggered when the player is within 0 – 5 metres. There are three dialogue lines, which are each associated with an audio file for the voice line and a volume to play at. In the future, we would like to provide more control to the authors such as combining one or more of these rules using AND, OR, NOT, XOR conjunctions.

The conversation node is placed according to the spatial rules associated with it. Avatars in the conversation node are placed uniformly around the F-formation based on the number of avatars, the F-formation shape, and how close they should be (their radius in the case of circular F-formations).

Story CreatAR provides two types of global events: traversal and timer events. Traversal events allow authors to specify an avatar to move (based on those created with the story content feature), a location to move to (a conversation node), and a speed to traverse at (walk, fast walk, run). We do not provide specific location options as we want to support site-agnostic stories. We provide the functionality for authors to move to conversation nodes as that was required for the stories we were supporting. Notably, this can allow authors to specify an avatar to move to another story element (if it is another avatar) by associating that story element with a conversations node. This can also be used to specify an avatar to be moved to a location with a given space syntax attribute set by associating the space syntax attributes to the conversation node the user chooses the avatar to move to.

The avatars move according to Unity's NavMeshAgent logic which uses A* path finding. An author specifies a timer event by inputting a time to wait (in seconds), which can be used to add timestamps to the story that traversal events can use. Both types of events use preconditions, which start this event only after all its preconditions have started/completed. Using "The Three Little Pigs" example, I can create an event for an avatar (e.g., wolf) to walk to a conversation node (e.g., three little pigs talking). Then, create a three second timer event that waits until that avatar (e.g., wolf) arrives at the new conversation node that includes other avatars (e.g., three pigs). Then, after three seconds all avatars (e.g., pigs and wolf) in the conversation node run to different conversation nodes (e.g., could be located at each of the pig's houses).

5.4.3 Placement Rules

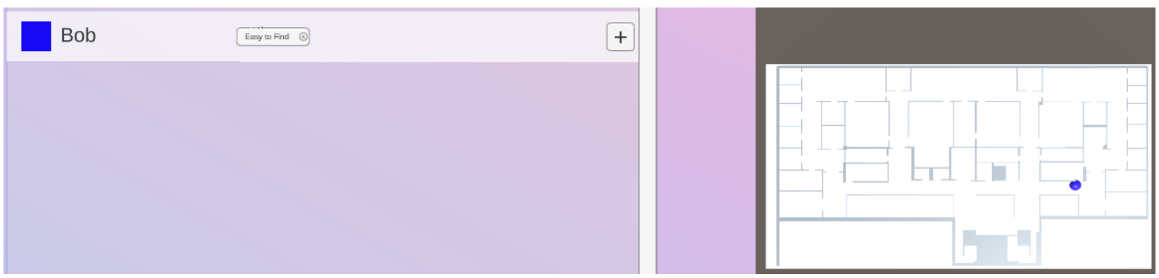


Figure 5.6: Bob associated with the "Easy to Find" Attribute

Authors create spatial rules to constrain the placement of their story elements. The spatial rules are based on the spatial analysis of an environment, and can be specified once and used for different environments. Since spatial rules can be complex (e.g., visual integration), we provide higher level spatial rules known as *attributes*, which can be associated with a story element. An attribute consists of a unique name and one or more spatial characteristics. The spatial characteristics currently supported by the tool are openness, visual complexity, and visual integration. We chose these space syntax characteristics based on what we believed would be useful for storytelling, but they were not derived from the best possible set of space syntax characteristics. Each spatial characteristic has a range of valid values: *lowest* (lowest 0 – 20% of values), *low* (20 – 40%), *moderate* (40 – 60%), *high* (60 – 80%), *highest* (80 – 100%), or *any* (0 – 100%). We derived the ranges of valid values from how our authors described space in their story scripts (e.g., highest visual integration). Therefore, we derived a five-point scale where each point is associated with 20% of the valid values. Story CreatAR provides several default attributes based on terms our

Attribute Name	Openness	Visual Complexity	Visual Integration
Hidden	Any	Lowest	Low
Easy to Find	Any	Any	Highest
Open Area	Highest	Any	Any
Closed Area	Lowest	Any	Any
Central Area	Any	Any	Highest
Outer Area	Any	Any	Lowest
Random	Any	Any	Any

Table 5.2: Default attributes with their corresponding spatial characteristics values.

authors used in their stories such as *hidden* and values they used to quantify them such as high. These default attributes create author friendly terms for a constrained range of values for the spatial characteristics. For example, an author may put a character in an *easy to find* space, which has highest visual integration (shown in Figure 5.6). Although, there may not appear to be a clear difference between attributes such as “Hidden” and “Closed Area”, our authors described placement of story content in their scripts using these different attributes, which we have associated with different space syntax characteristics. A full list of the default attributes can be found in Table 5.2.

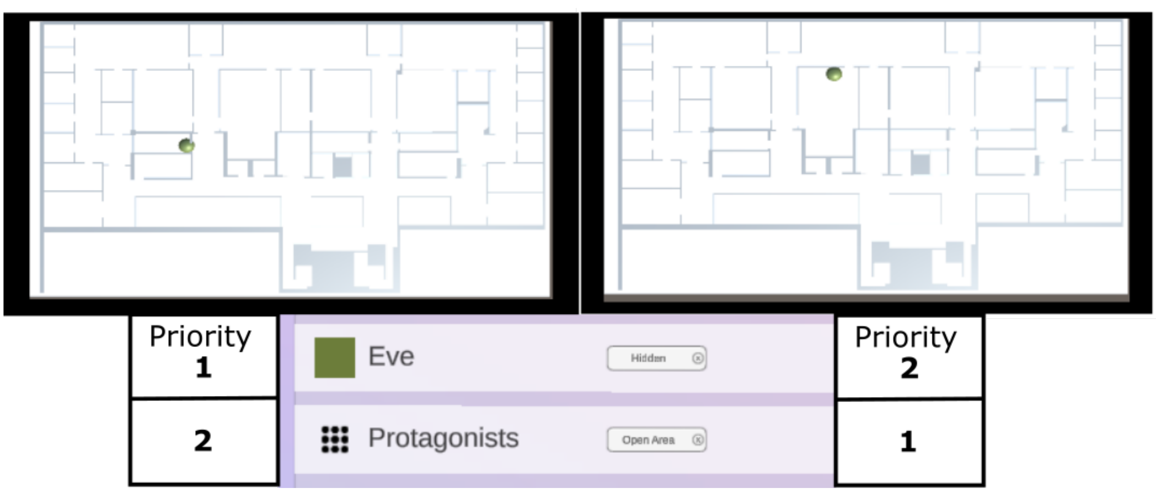


Figure 5.7: Left: Eve placed with “Hidden” as highest priority. Right: Eve placed with “Open Area” as highest priority.

As a story element may be part of a group with several attributes, it requires prioritization of the attributes. Attributes given to a story element have a higher priority than attributes it receives by being part of a group. This permits story elements within a group to have a unique placement. This priority mechanism draws inspiration from inheritance in object-oriented programming as the super class (or the group) has the general attribute and the sub-classes (or the story elements) have specific attributes. For example, the group may have "Hidden" as the general attribute, but an individual story element may have a room constraint. Story elements may have up to three attributes individually and for each group they are part of. We allow authors to specify three attributes as we want some flexibility, however, more than three may get confusing due to the current selection of only three space syntax characteristics. The ordering for the priority of the attributes is then based on the order the attributes were added, with the attributes first added having highest priority. Authors can override these priorities by editing the story element and inputting a new priority for each attribute, where one is the highest priority and n is the lowest. For example, Eve belongs to the group "Protagonists" (shown in Figure 5.7). The author wants Eve to be placed in an open area, but if no suitable location exists, then Eve should hide. Protagonists will have the attribute *Open Area* and Eve will have the attribute *Hidden*. "Protagonists" does not appear on the floorplans as it is a group and not an object to place. The default priorities for Eve are one — *Hidden*, two — *Open Area* (placement is shown in the left of Figure 5.7). The author must manually input *Open Area* as priority one to get their desired placement (desired placement shown in right of Figure 5.7). The attributes and their priorities are used to place the story elements in appropriate locations. Conversation nodes can be similarly placed. The author then tests the possible placements across multiple floorplans, and once satisfied, the author saves the placement into a new Unity Scene where they can make minor adjustments. For example, an author may manually orient a bed to face away from a wall. Any modifications the authors make in the Unity Scene will be lost if the author returns to Story CreatAR to make more placement edits as the spatial attributes will override the manual modifications because the manual adjustments may not be able to be expressed with the spatial rules available to the author or they may be contradicting the spatial rules an author already specified. Any new settings for the story will not include the manual adjustments, which is reasonable as the manual adjustments are likely specific to the floorplan the author is using. A site administrator may perform the manual modifications themselves on site as the context of the location may change an appropriate placement. For example, in a school a site administrator may move elements placed in a locker room to a more appropriate location to enter.

Figure 5.8: Bob is placed by the room constraint "Bob's Bedroom"

Another form of spatial rules are room constraints. Authors can use Story CreatAR to create rooms in their story. Rooms are defined by their size (small, medium, large), which are then automatically mapped to a physical room in the environment. We provide static room dimensions rather than author-specified as this allows the story to be more adaptable, the size property is always satisfied, and we imagine that most authors do not have specific room dimensions for all the rooms in their story. A story element can be assigned a room as a placement rule such that the story element is required to be placed within that room. For example, the story element "Bob" may be associated with the room "Bob's Bedroom" such that at the beginning of the story Bob is placed in Bob's Bedroom (shown in Figure 5.8). Room constraints can also be associated with conversation nodes to place story elements in the conversation in a specified room anytime in the story experience.

5.5 Use Case

An author may add a new floorplan to use for their story. In this case (Figure 5.9) we added a floorplan of a small museum room in the Museum of Natural History. We have five objects (security camera, dog, doc and police, planets, demon circle) that each belong to a unique room with a specific spatial attribute. These spatial rules are visually associated with the objects in the form of tags. Each object in the list is associated with the same color sphere in the floorplan. Objects are first placed in

Figure 5.9: Different placements

their room and then placed based on their spatial attribute. Note that the ordering of the attributes does not affect this, an object will always be placed in the room assigned to it. For example, the security camera is in an "open area" inside a large room. The security camera in both options is placed in the same room. Option one has its placement in front of the door and option two has it in the corner across from the door. Both are possible options that have high openness and that satisfy the author defined spatial constraints. Additionally, it is easy to imagine both as being suitable locations for a security camera.

Using Story CreatAR, authors are able to see placement options they may not have previously considered as appropriate. This is useful in two ways. First, an author may realize they need to reconsider the spatial rules they used or they may realize the need to specify more specific spatial rules (e.g., open area and not close to the door). Second, an author may have had a specific placement in mind and this not only helps them to place their objects more generally, but also provides more ideas of suitable locations. This is important for a locative story that can be played in many different locations.

5.6 Background Analyses

5.6.1 Isovist Analysis

DepthMapX is used to get the space syntax values for each position in a floorplan. The procedure for using depthMapX is as follows.

1. We use Inkscape [72] to convert a 2D image of a floorplan to a vector format (e.g., Drawing Exchange Format, DXF) that is taken as input to depthMapX for performing the desired space syntax analysis.

2. Authors using Story CreatAR can upload their floorplan, which triggers automatic spatial analysis technique(s) from depthMapX using a command-line interface (CLI) [130], which will generate a CSV file containing values for some space syntax characteristics.

3. With the CLI, we first prepare the floorplan in depthMapX for visibility graph analysis (VGA) by defining the grid size and the starting coordinate (x,y) of

the floorplan.

4. Next, we perform the VGA using the visibility mode (looking at axial lines) and then using the isovist mode. The output from VGA (CSV format) is a set of numerical space syntax values based on visibility and isovists for each position in the floorplan, which is relatively easy to use in calculations as we are working with numerical values.

5. The CSV file is saved in Unity so it does not need to be recalculated. From the CSV file we can extract visual integration, isovist area (openness), and isovist perimeter (visual complexity), which are then linearly scaled to usable ranges in the interface (0 – 100) using the following conversion.

   $f(x) = [((x - min) * (b - a)/(max - min)] + a$, *where a, b are the minimum and maximum values of your target range and min, max are the values of your current range.*

6. These values are loaded into Story CreatAR and used for placement rules.

5.6.2 Convex Analysis

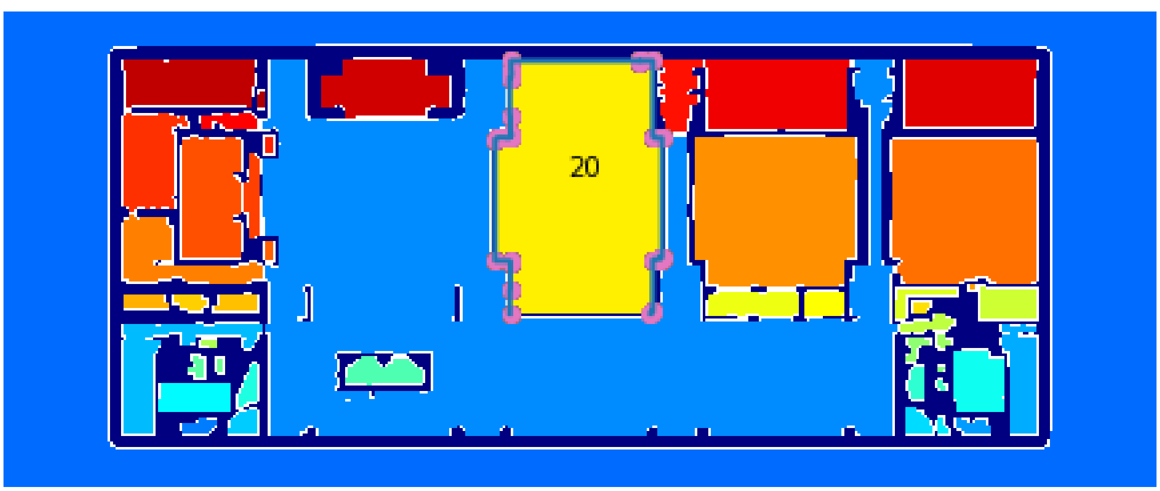


Figure 5.10: The color-coded room output of AFPlan.

AFPlan is used to identify rooms and doorways in a floorplan. The process of using AFPlan is as follows.

1. AFPlan takes a 2D image (.jpg, .jpeg, or .png format) of the floorplan as input.
2. The image goes through morphological cleansing to reduce noise.
3. To divide the regions into rooms, machine learning and convex hull closing algorithms are used to close gaps in the floorplan.
4. Then, AFPlan performs connected component analysis to detect and color-code rooms.
5. AFPlan outputs a color-coded image (Figure 5.10) and a CSV file containing room vertices and areas.
6. The CSV file is saved in Unity and used in Story CreatAR to constrain placement of a story element to a room through the assignment of floorplan specific room IDs.

Rooms constraints can be adapted to new locations. Since the room properties are generic to all floorplans, we can automatically assign a room to a new location by satisfying the room properties specified by the author.

5.6.3 Socio-spatial Theories

ProxemicUI [23] is used to create proxemic (distance/orientation) relationships for conversation nodes. We have a tracker assigned to each entity (story elements, conversations, player) to monitor their 3D position and orientation data, which is used to check if proxemic rules have passed/failed. For example, the proxemic rule may detect when the player is facing a conversation AND when the player is within 5 metres of the same conversation. Story CreatAR uses these proxemic rules to create proxemic triggers for conversations to start and for choosing a radius (in terms of the proxemic distances) to place avatars in a conversation. Our F-formation algorithm to place avatars in a circle utilizes this radius to determine how closely avatars should be to the center of the circle (conversation).

5.6.4 Placement Algorithm

After we receive the spatial analysis values from depthMapX and the author-defined placement rules, we can place the story elements. We have adapted the open source

Unity plugin from Reilly et al. [111] (used to place objects in AdventureAR and ScavengAR) to read placement constraints for our story elements and to use a different space syntax characteristic (visual integration rather than connectivity) in the placement. Story CreatAR creates a JSON file specifying the rules that will be inputted to the plugin. The plugin then performs a greedy algorithm to satisfy the placement constraints. If no position that satisfies all placement constraints is found, the rules are relaxed (starting at lower priority rules) until there is a plausible location.

5.6.5 Rigging RocketBox Avatars

As mentioned in our Story CreatAR Design Chapter, we use the Microsoft Rocketbox Avatars as our mentor for the Snap Creative Challenge was one of the contributors to this library. As the Rocketbox Avatar is a large library, we imported a small selection of these avatars (about 10) into Story CreatAR. These avatars were rigged as humanoids. We created an *Animator Controller* to control the sequence of animations for the avatar. The Animator Controller is based on a generic controller provided by the "SteamVR" package called "JoeJeff". This by default provides walking, turning, crouching, airborne, idling, and jumping animations and the logic for switching between these animation states. We adapted the controller to also include a talking animation such that when an audio clip plays from the avatar's audio source, the talking animation is triggered.

5.6.6 Custom Development Opportunities

Authors can import their own 3D props, specific avatars from the Microsoft RocketBox Avatar library and audio files, which provides ample opportunity for story customization. Authors can also customize the experience to fit their own location by adding a new map and using it for their story. Authors also have the opportunity to make manual adjustment to story content placement or to have custom features implemented once they have exported their story to a Unity Scene. For example, the author may ask a developer to implement additional story specific features not available in the interface (e.g., ability for the player to pick objects up).

5.7 Limitations and Future Work

Our authors were introduced to relevant literature such as spatial analysis concepts, new media examples and literature, and AR stories that a typical user of the system may not be exposed to. Thus, we must disclose that our authors may have been biased by our research in using spatial analysis to facilitate dynamic placement of locative AR narratives. Therefore, it is unknown whether naive users would also create these types of placement constraints in their story script (e.g., number of doors per room, where conversations are placed within a room, etc.). Furthermore, authors also collaborated with the developers of Story CreatAR during the creation of the stories, however, we expect most authors would not have access to this type of expertise. Authors may have access to developers to help inform them on the limitations and features of the medium they are working with and even to implement new features for them.

In future work, we would like to compare the spatial analysis placement produced by Story CreatAR to manual, and random placement for different stories in AR/VR. This is discussed in more detail in Section 9.5.1. The attributes we provide by Story CreatAR were chosen based on what we believed to be a set of meaningful spatial qualities, but we require more research to find a comprehensive set. For example, we may want to include *accessibility* (how easy it is to get to a certain location). We created *attributes* to hide the inherent complexities of spatial analysis, but we need to examine if the set of attributes we provide are meaningful and that the attributes are understood and used effectively.

5.8 Summary

We present Story CreatAR in terms of an expected workflow and the features available to authors. We detail a potential use case of the tool and background analyses used in Story CreatAR. Additionally, we detail limitations of our work and future directions that we will use to determine the usefulness of our tool.

Chapter 6

Evaluation of Authors using Story CreatAR

6.1 Introduction

This and the two subsequent chapters detail work that is currently being revised for submission to Designing Interactive Systems (DIS) conference 2022. The thesis presents more reflection and discussion on a wider variety of study artifacts. This chapter details the study design and the subsequent chapters detail the results and discussion.

Ryan and Eric participated in this study with us. However, Anna had other commitments and therefore her supervisor, Amy filled in for Anna. When we refer to all authors in this section, we refer to Ryan, Eric, and Amy.

In this study, we worked directly with authors during different authoring phases to find how authors used spatial relations both in their story representations and when using Story CreatAR, and how useful the spatial relations provided by Story CreatAR are to the author. An overview of the study design is provided in Table 6.1, which consists of three phases: one where the author creates a story graph, one where the author uses Story CreatAR to implement their story using (a) only their script and (b) only their graph, and one where the developer uses only the script and only the graph to implement the story in Story CreatAR. Different sections of each author's story was chosen for the author to implement in Story CreatAR using each story representation as reference, which were different sections than used in the developer implementation. One researcher and I participated in the sessions where the author created their graph and when the author used Story CreatAR. Another researcher and I created the authors stories in Story CreatAR using only the graph and only the script. We did not counterbalance the phases as the phases involved in using the Story CreatAR interface relied on having the graph representation created.

We investigate the benefits and limitations for an author creating a graph for a nonlinear, interactive, spatial story. We investigate users individually using the script and graph in Story CreatAR to isolate the pros and cons of each method. Although, a combination of multiple story representations is expected. Additionally, we compare authors (typical users of our system) and researchers (who can implement additional features themselves) use of Story CreatAR. We collected video recordings of our meetings with the authors and as a group of six researchers, performed a thematic analysis on the comments and behaviors displayed by our authors throughout these sessions. In the following sections the study phases and data analysis will be described in detail.

6.2 Study Design

All authors were provided an informed consent form and returned it signed via email. As this study was held in the midst of the COVID-19 pandemic, all meetings with the authors took place remotely via Microsoft Teams [6]. A collaborator and I met individually with each author in twice-weekly sessions for two – four weeks during each phase. In the developer implementation phase, me and another developer implemented parts of each story. Throughout phase one and two, authors were asked to employ a think aloud strategy and we would prompt for more details as necessary. Each phase was concluded with a semi-structured reflective interview. The research ethics board (REB) approval letter and the consent forms for this study can be found in Appendix E.

6.2.1 Phase 1: Creating Story Graph from Story Script

In this session authors were introduced to the online graphing tool called Miro [11]. Miro allowed authors and researchers to collaborate online in real-time using a WWW-based drag and drop canvas. We briefly (five minutes) introduced some of Miro's features we thought to be useful such as the ability to add text, frames, arrows, and shapes to the canvas. Next, we took about seven minutes to introduce our example graph of The Three Little Pigs shown in Figure 6.1. As we are not restricting authors on how to represent their story graphically, we chose to present an example graph to help inspire ideas for authors. This additionally showed some of the type of information we wanted included in the graph (e.g., where characters are located). In this graph we demonstrate a start and end node (black circles), showing where

Order	Research Phase	Summary	Sequence	Duration
1	Story Graph Representation	An author represents a section of their story as a graph representation using Miro (online graphing tool).	We explained Miro features we thought would be useful, we showed an example graph for the children's story The Three Little Pigs, the author uses Miro to create their graph, the developers prompt the author with questions, and the author adjusts their graph.	6–7 sessions per author (mean of 53 min.)
2	Author using Story CreatAR	An author directly uses Story CreatAR to implement their story in two ways. 1) Author uses only the graph 2) Author uses only the script	We provide a brief overview of Story CreatAR features, the author implements their story, and we follow up with interview questions.	4 sessions per author (mean of 1 hour)
3	Developer using Story CreatAR	A developer uses two methods for implementing an author's story in Story CreatAR. 1) Developer uses only the graph. 2) Developer uses only the script.	The developer familiarizes themselves with the graph and the script, they use the Story CreatAR interface to create their initial placement, then they create additional features required for the story, test and record the output in VR, and finally meet with the author on their thoughts of the VR realization.	4 weeks of development and 1 demo session per author (40–50 min.)

Table 6.1: Overview of the Phases Used in Story CreatAR Evaluation

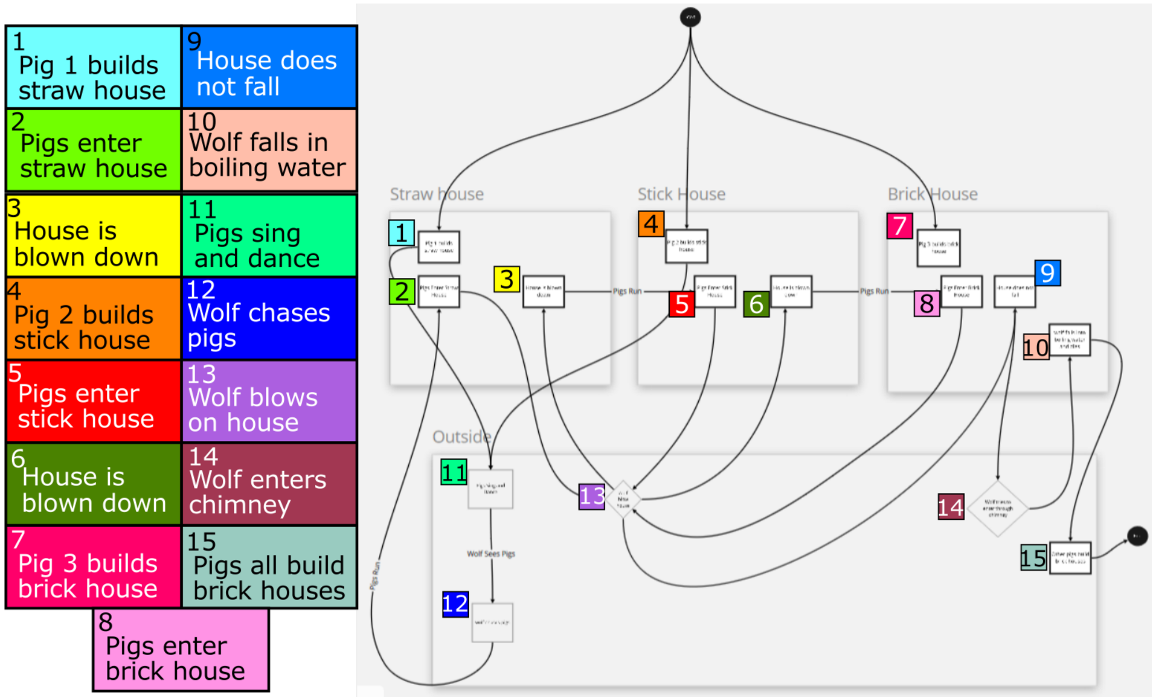


Figure 6.1: Graph representation of "The Three Little Pigs" created by the researchers.

the story starts and stops. We organize it by frames used to show locations (straw house, stick house, brick house, and outside). We also represent events in the story as nodes (squares/diamonds) in the graph and transitions between those events as arrows connecting the nodes. As we were showing our sample graph to the authors they were welcome to ask questions. Amy noticed a logical error in our sample graph, which is illustrated when she asked regarding Event 13 (in Figure 6.1), "there are three arrows coming out of this event, how do you know which one to choose"? Ryan and Eric both immediately reflected on the sample graph in relation to their story. Ryan announces that he will begin with the endings in his story as these are simpler than the beginnings. Eric was worried that his story is too long (in terms of the script) and large (in terms of rooms). We did not constrain authors graphs as we did not want to bias the authors towards a certain representation, all stories were vastly different, and we wanted to see how authors would naturally represent space in their graph.

In the initial sessions with the authors, we suggested that annotating the script may help with a clearer translation to the graph. The annotation identifies nodes

Table 6.2: Prompts for authors while creating their graphs.

Prompts During Graph Creation Phase
How can you show character dialogue?
Describe what the room is like spatially (e.g., size).
How can you show on the graph what other objects are located in rooms?
What was the biggest challenge to implement in the graph so far?
Do you think there is anything you could not implement in the graph that you would like to?
Do you think there's anything you could implement in the graph that would be hard to represent in the story?
Does the position of an entity on the graph have meaning? Does an entity's proximity to another entity have meaning?
Are there any events that are triggered by getting close to characters?
Are there any events that are triggered by facing a certain direction?
Are there any arrangements for avatars while in a conversation (e.g., shape)?

Table 6.3: Reflection interview questions for graph creation phase after group session.

End of Graph Phase Interview Questions
1. Based on the other author's graphs, what would you do differently?
2. How would you change the representation of space in your graph?
3. What aspects of your graph accurately represent the story? What aspects do not accurately represent the story?
4. How should you distinguish between what goes on an arrow (trigger) or shape (entity)?
5. What additional details would you like to represent in your graph? How would you represent these details?
6. Did you ever think of how to implement the story as a computer scientist?
7. How much effort would it be to create your entire graph? Is this feasible?

and transitions in the script, which translate to structural elements in the graph. Some suggestions for items to annotate were characters, spatial descriptions, dialogue, actions, and animations, which influenced how Amy and Eric annotated their script. Throughout the sessions we prompted authors a couple of times to consider different aspects of their graph including logical and spatial aspects. A full set of these prompts are found in Table 6.2. We prompted authors to ensure that they would provide information on the location of story elements, this resulted in more focus on the spatial aspects. However, how an author described and represented the spatial rule was their choice. The authors modified their graphs in response to these prompts.

We held a 1.5 hour group session with the authors, where each author took a turn sharing their graph and their experience with the others. We allocated 20 minutes per author (total = one hour) to present their graph. We prompted the author to do the following while presenting their graph (in order): explain their graph, explain how they represented elements in their story (using shapes, colors, groupings, etc.), the process they took to move from their script to the graph, and to explain what they would do differently in another graph. During this time the other author and researchers were able to interrupt the speaker to ask questions. After all authors presented their graph, they had a 30 minute discussion (making the total 1.5 hours) where authors could ask and address any additional questions and comments. We were able to compare the processes of different authors and encourage author reflection in the group session. Afterwards, we held a 15–30 minute individual session with each author where we asked several reflection questions found in Table 6.3

6.2.2 Phase 2: Authors using Story CreatAR Directly

In this phase authors used Story CreatAR in two parts (two one-hour sessions per part). In the first part the author implemented their story while referencing the graph. In the second part the author implemented their story while referencing the script (different part of story than used for the graph). As we did not want the authors to have to download Unity, we opted for the authors controlling my screen. We used the screen control feature in Teams. Depending on what representation the authors were referencing (graph or script), that was available on the screen as well (for recording purposes).

Authors were shown the assets acquired by the researchers for their story (e.g., tea tables, doors, desks, etc.). We expect authors of our tool would have to acquire these assets themselves, which can be readily found in online databases. Then, we took five minutes to highlight some of the basic features available in Story CreatAR (creating a story, inputting name/title, and ability to add story elements, add conversations, create room rules, placement rules, timer events, and traversal events). The authors followed a think-aloud approach while they worked on implementing their story during the remaining time, asking us questions when they felt necessary. In the last session we held a 30 minute interview to gain insights on their experience and how we can improve Story CreatAR. The list of interview questions follow.

1. Which approach (graph or script) did you find better to create this story?
2. If you were to implement your story over again using Story CreatAR, would you reference the graph or would you reference the script or would you reference both?
3. What do you think the benefit was from creating the story from the script and what do you think the benefit was from creating the story from the graph?
4. Now that you've used Story CreatAR do you think there is anything that you could add to your graph to make it more useful for our tool?
5. What are three functionalities or features that you think would be most useful to be added to Story CreatAR?
6. What functionality did you like and dislike in Story CreatAR?
7. What difficulties did you face when using Story CreatAR?
8. How do you think we could improve Story CreatAR?
9. Do you think a new user of Story CreatAR would you be able to use the interface by themself or would they need some type of documents or instructions? Or would you need a one-on-one session with an expert to help?
10. Here when we create a room right now, you can specify if the room is small, medium, or large. Do you think it would be useful to specify how close or how far a room is to another room?
11. Do you think there is a need for rules that detect when the player is facing a certain direction or object or avatar?
12. In the conversation node we offer the formation of a circle for the conversation. Do you think other types of formations could be useful?
13. I feel like the event logic may have been a bit confusing. How do you think that could be simplified?
14. You did not click the "Save Scene" button very often. Why not?

6.2.3 Phase 3: Developers implementing an Author's Story

Myself and another researcher worked on the developer implementation. We each implemented three story parts, resulting in six total. Each story segment was about six minutes of story experience. For each story, there were two parts to implement: one using only the graph and the other using only the script. Researchers documented their process in a Word document detailing what they did, future work ideas, decisions they made and why, what they had trouble with, and what they found interesting. They began with a broad overview of what to implement (characters, rooms, conversations, animations, events). Then, they implemented as much as possible using Story CreatAR. This was followed by saving the intital placement and events into a Unity Scene and making minor adjustments to the placement of objects (e.g., turning a painting to face the appropriate direction). Story-specific events were then added (e.g., adding lighting effects) directly in Unity. Lastly, the stories were deployed in VR using the Oculus Quest 2 [9], iterated on, and finally recorded to show the authors. We tested in VR because the deployment site (Dalhousie Campus Building) was inaccessible due to COVID-19. The researchers presented the video recordings of the experience in VR to the authors, where both authors and the researchers were able to comment on the video at any time by pressing pause. The researchers described decisions they made that either were not specified by the script or contrasted the script and why. The researchers showed the video of the resulting story experience in VR for the graph representation and then for the script.

6.3 Data Collection and Analysis

Each author provided a complete story script and a section of the script translated into graph form, where size of the section varied from author to author. For example, Amy implemented two of 16 scenes from Tyson's Peak, Eric implemented the beginning of his story before three major story paths, and Ryan implemented most logic in his story.

An overview of the data we collected from each of the three phases is shown in Table 6.4. In Phase One, we collected Miro logs, which inform when an object was added, edited, or deleted. We also have video recordings of the sessions where we

Phase	Data Collected
Phase One	Miro logs, video recordings of the sessions, list of all questions and answers
Phase Two	Counts of relationships used in Story CreatAR, video recordings of the sessions
Phase Three	Developer journals, .apk (VR installation) file for the story, video recording of story in VR, written comments from authors on VR recordings, and video recording of researchers showing authors the VR video recording.

Table 6.4: Overview of data collected in each phase.

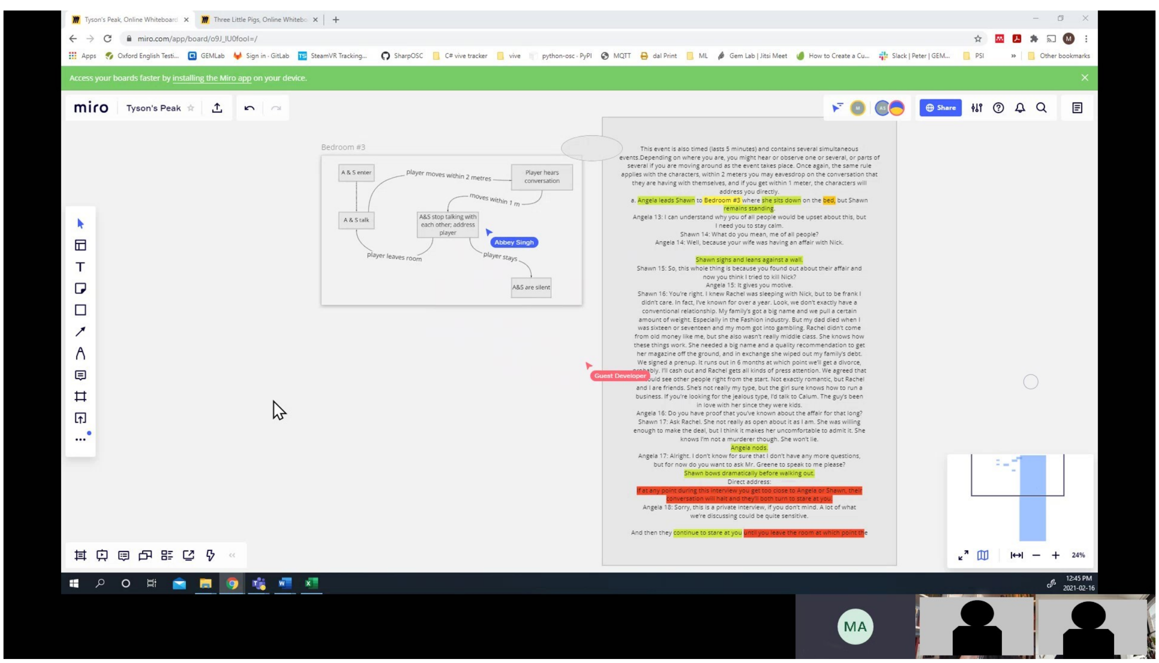


Figure 6.2: Amy creating the graph in Miro

directly interacted with the authors. In the video recordings, we recorded what the author was interacting with/looking at in the phase (e.g., for the graph sessions we recorded the Miro board the author was modifying), as well as the author's expressions (if their video camera was on), and the dialogue exchanged during the session as shown in Figure 6.2. We extracted the audio file from the video recordings using Sony Vegas Pro 14 and then all audio files were automatically transcribed using Microsoft Azure's voice recognition system, which were then reviewed and adjusted by researchers (i.e., correcting misinterpreted words). From the transcriptions, we noted all questions and answers that were asked during the phases. We also collected data regarding what relationships authors used in Story CreatAR (e.g., number of placement rules used, number of times viewing the placement in 3D, etc.). From the developer implementation (Phase Three), we have developer journals where we detailed what we did, future work ideas that came up, and difficulties we faced. We have the .apk file (installation file for VR) that can be uploaded to a VR headset to experience the story and the video recording of the VR experience. The authors additionally provided written comments after looking carefully at the VR recording.

We performed a top-down deductive coding method to understand author's uncertainty as we wanted to measure how confidently authors described space in the three approaches and what difficulties authors encountered. I followed a similar approach to the *deductive* thematic analysis (TA) discussed by Braun and Clarke [37]: I watched video recordings and became familiar with the data, generated initial codes based on aspects of uncertainty, improved those initial codes by reviewing the data, and then coded the videos. In this method, two researchers coded each video until they met an acceptable inter-rater reliability (IRR) (greater than 0.7), when met they were able to divide the remaining videos. We calculated the IRR by percentage of annotations coders agree on [64]. Despite researchers criticising the use of percentages of agreement due to overestimation of the IRR (agreement occurring by chance), this is not as much of an issue with our video coding scheme. There are many aspects in the video and several codes, making it is less likely for coders to agree by chance. We calculated the percentage coders agree by parsing through each of the codes generated by the two researchers, we quantified how many of those codes captured the same information (i.e., same code over similar time-frame), and then calculated the

ID	Original Codes	Adjusted Codes
1	*Confusion*: Verbally unsure what to do or takes awhile to answer. Ex: “I’m not sure what is best to do.”	(Renamed) *Logical Confusion*
2	*Giving Up*: Negative attitude, expressed dissatisfaction, loss of enthusiasm. Ex: “I can’t do anything else.”	N/A
3	*Asking Developer/Expert*: Author asking a question to a developer or expert. Ex: “Does this make sense?”	N/A
4	*Making Mistakes*: Author thinks they are doing one thing but actually doing something else. Ex: Adding story elements to a group to place them close together.	(Same definition) *Making Mistakes*: Usually an action the author performs.
5	*Changing Mind*: Starts something and does something else without seeming like they made a mistake. Ex: Author creates new placement attribute, but cancels and chooses a default placement attribute.	(Same definition): *Changing Mind*: This is an action the author performs.
6	N/A	*Developer Suggestion*: Developer hints at author next steps. Ex: “What does the “Initial Avatars” list mean?”
7	N/A	*Technical Confusion*: Author is confused about technical aspects. Ex: “I want to make a circle, but I’m not sure how to change the shape”.
8	N/A	*Author Missing Details*: Author lacks details in story representation. Ex: Author wants to specify dialogue in Story CreatAR, but did not include the dialogue in the graph.
9	N/A	*Author Suggestion*: Author suggests a new feature or change to existing feature. Ex: “This screen would be better named as ’Movement Event’”.
10	N/A	*Author Likes Something*: Author says positive comments. Ex: “I like being able to place avatars in a circle formation”.

Table 6.5: Original (left) and new/adjusted (right) codes used in our top-down coding.

number of codes the researchers had the same over the total unique codes produced by the researchers. We began with the codes: *confusion* (verbally unsure), *giving up* (negative attitude), *author asking a question to a developer*, *making a mistake*, and *changing mind* (or task). As we went through the initial videos, we improved the codes by adding *developer makes a suggestion*, *author missing details*, *author makes a suggestion*, *author likes something*, and divided *confusion* into *logical* and *technical* confusion. These new codes helped clarify existing codes and capture additional data in our sessions relevant to our research questions. For example, authors made suggestions regarding the placement screen in Story CreatAR, which directly relates to our research objectives. Table 6.5 summarizes the original and adjusted codes. While coding, we also noted interesting observations.

I also followed a similar approach to the *inductive* thematic analysis described by Braun and Clarke [37] on all the videos that were recorded as our research is exploratory. Similar to the deductive TA, I and all but one other researcher was familiarized with the data, and then we noted our observations, and during an affinity diagram session we searched for categories. Our approach differs in that we named our categories and then further reviewed them, producing themes. A researcher who did not participate in the uncertainty coding noted potentially relevant or interesting observations while watching the videos. We used this researcher's annotations along with potentially relevant or interesting notes made during the uncertainty coding to create categories for each phase during multiple affinity diagram sessions, described in the next section.

6.3.1 Affinity Diagram Data Analysis

We created one affinity diagram for the graph and interface approaches as they were similar and we were still able to compare the approaches based on color-coded annotations. We created one affinity diagram for the developer approach. Six researchers participated in all affinity diagram sessions online using Miro: two sessions for the graph and interface, and one session for the developer. We followed a similar process for creating both affinity diagrams. First, for each video I derived a comprehensive set of qualitative annotations from the sets of individually analyzed annotations. Second, I created a Miro board and added the annotations to it. Since there are six participants in this activity, I randomly divided the annotations into six groups. During the affinity diagram session, we began by silently reading through our section of annotations and moved them into the canvas to form groups. During this time, we were able to move other researchers' annotations freely. We continued to move the annotations in silence until we were no longer adjusting annotations to different locations. Then, we discussed if applicable, any disagreements between researchers. Lastly, we collectively named each group and sub-groups, and reorganized the annotations if necessary.

For the graph creation and interface approaches, we had a group affinity diagram session on a subset of the annotations that lasted two hours. For this, I prepared annotations based on eight of the 32 videos: four videos of Amy during the graph creation approach and four videos of Eric using the interface approach. From our 247 annotations we created six broad categories and 36 sub-categories. Next, I added the remaining annotations, placed them within the categories already created, and added new categories as necessary. From the 1087 unique annotations, we kept the six broad categories and had 74 sub-categories. Then, we held a group session to revise the annotations and sub-categories I added, which lasted about one hour. This resulted in creating a new category and several sub-categories (78 total). Lastly, each researcher was assigned one or two categories to review, modify if necessary, and summarize. In parallel, I reviewed all of the categories and sub-categories and produced summaries. Notably, this lead to the creation of more categories: misunderstanding of spatial analysis concepts was sub-divided into six sub-categories, session description was divided into three sub-categories, and author insights/comments was divided into six sub-categories. An overview of the categories for the graph and interface affinity diagram is presented in Appendix D.

For the developer approach, we were able to create the categories during an hour and a half session. In this session, we had 98 annotations for the three videos, which resulted in 11 broad categories and five additional sub-categories. An overview of the categories are presented in Figure 6.3. Only two of the 11 categorizes were sub-divided (author discoveries and spatial considerations).

Figure 6.3: Summary of categories from the affinity diagramming sessions for developer phase.

6.4 Summary

I described an evaluation of Story CreatAR. We evaluated with three authors over three phases: author created graph representation, author used Story CreatAR interface to implement two parts of their story, and a developer used Story CreatAR to implement two parts of an author's story. We performed a thematic analysis to derive the results presented in the next Chapter.

Chapter 7

Results of Authors using Story CreatAR

7.1 Introduction

From the data we collected and the affinity diagrams, we derived several results. These results centered on author's experiences creating their story graph and author's and developer's experience using the Story CreatAR interface, with an emphasis on how they represented spatial characteristics. I discuss how author's used Story CreatAR features and how author's used and thought about space.

Table 7.1 provides an overview and frames the results presented in this section. We had a variety of different experiences across the authors, informing how they used and understood space, which is further detailed below.

7.2 Resolution of Uncertainty

We present uncertainty counts for authors in the graph creation and author using interface phases. We do not include uncertainty counts for authors in the developer phase as authors were not creating anything or using our tool, but instead the authors were commenting on the results from the developer phase. The uncertainty counts characterizes where and how much each author struggled and how their struggle differs when using different story representations.

An overview of the uncertainty counts for the *graph creation* phase is presented in Table 7.2. Although, not all codes would necessarily capture uncertainty all of the time (e.g., changing may not come from making a mistake), but the majority of the annotations capture uncertainty. Amy and Eric asked the most questions to the developers. Ryan may have asked less questions due to his previous experience creating a graph representation of his story and due to his technical expertise. Eric was aided the most with his graph, with over double the number of suggestions than Amy and Ryan received. This could be due to Eric thinking in a less logical,

Sections	**Amy**	**Eric**	**Ryan**
Resolution of Uncertainty	Amy was the most independent and asked many questions, but still had some uncertainty.	Eric was the most reliant on technical support as he had the most uncertainty, perhaps due to the lowest technical knowledge.	Ryan showed less uncertainty than Eric, but gave many suggestions.
Story Script and Graph Creation	Created a foldback structured graph Objects in graph placed based on relativity versus script placed by spatial characteristics.	Created a branching graph. Described NPC movements and player interactions more using graph.	Created a broom, opportunistic, and hidden structured graph. Provides more spatial description using script than graph.
Developer Experience	Amy supported spatial decisions made by developers.	Eric also supported spatial decisions, and found the F-formation used suprisingly agreeable.	Ryan realized he did not specify all that he wanted to in his story representations and corrected the number of doors for one room.
Story CreatAR Features	Amy considers how long it takes an avatar to move.	Eric had difficulty specifying proxemic distances and incorrectly interpreted proxemic distances.	Ryan had difficulty specifying proxemic distances
Space and Placement	Amy iteratively explored multiple placement options and structured her placement around rooms.	Eric struggled with maintaining flexible placement, but viewed the 3D preview the most.	Ryan translates characteristics to placement attributes and creates labels for placement that is not easy to do in Story CreatAR.

Table 7.1: Overview of results

Code	Amy	Eric	Ryan
Logical Confusion	15	20	19
Giving Up	0	0	0
Asking Developer	69	71	25
Making Mistake	5	1	3
Changing Mind	15	11	18
Developer Suggestion	30	81	18
Technical Confusion	1	2	3

Table 7.2: Uncertainty coding summary for graph creation phase.

programmatic manner. None of our authors gave up during this phase, which shows their resilience.

An overview of the uncertainty counts for the *interface* phase are presented in Table 7.3. For a given column in the table, "AuthorName Graph" refers to the author using their graph representation to implement their story in Story CreatAR and "AuthorName Script" refers to the author using their script. Eric, our least technical author, asked the developers significantly more questions than the other authors (over double), which resulted in significantly more hints and suggestions from the developers. This could imply a technical roadblock that he needed to overcome while using the interface. Interestingly, Ryan made the most suggestions, which could be since he is the most experienced with digital creations from his experience with video games. Amy was the most independent (least amount of developer suggestions) and encountered the least amount of technical confusion. All authors made more mistakes and gave more suggestions when working with their script compared to working with their graph.

7.3 Story Script and Graph Creation

In this section I describe the structure and flow of authors' graphs to provide context on the appearance of the graphs and how they relate to previous literature. I describe how authors represent spatial rules in both their story graph and their story script. The description of the authors' graph and the spatial rules were derived from visual inspection of the authors' story representations. Additionally, I summarize the experiences with using the graph and the script. The summaries are derived

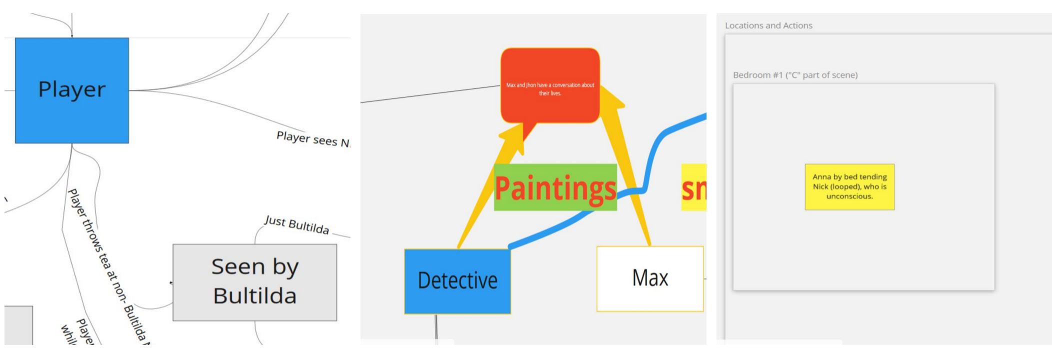
Code	Amy Graph	Amy Script	Eric Graph	Eric Script	Ryan Graph	Ryan Script
Logical Confusion	21	7	8	15	11	5
Giving Up	0	1	0	0	2	2
Asking Developer	28	18	48	59	20	20
Making Mistake	9	2	3	8	4	6
Changing Mind	2	0	2	0	3	1
Developer Suggestion	7	0	23	32	9	13
Technical Confusion	5	1	11	9	11	3
Author Missing Details	1	0	3	2	6	2
Author Suggestion	14	16	2	13	23	41
Author Compliments	11	10	3	6	5	6
Changing Task	6	6	1	3	5	1

Table 7.3: Uncertainty coding summary for interface phase.

from the affinity diagram categories. To create the summaries for the affinity diagram categories, two researchers created summaries independently for each of the categories/subcategories, which were later merged.

7.3.1 Experience with Graph

Author's Graph Representations



(a) Spill (b) Standville Museum (c) Tyson's Peak

Figure 7.1: Snippets of each author's graph

The complete graphs for each story can be found in Appendix C and a snippet of each graph is shown in Figure 7.1. Despite authors all given the same instructions, shown the same example, and provided the same medium to work within, all graphs were vastly different and are representative of different narrative representations found in literature [39].

Standville Museum (Figure 7.1b) consists of two separate graphs. The first graph consists of varied sizes and colors of shapes, text, sticky notes, and arrows. This graph actually *shows* where objects should be placed as if it was using the canvas as a map. The objects are placed in relation to other objects and events. The first graph's sole purpose is to show the placement and movements of objects, events, and characters. Eric created the second graph after prompts from the developers to show more causality in the graph. Eric uses boxes arranged left to right to show temporal causality, where events occurring simultaneously are aligned vertically. Eric's graph is a clear example of a *branching graph* [39], where the player can choose one of three pathways (by selecting a clue) that lead to largely different experiences.

Spill (Figure 7.1a) is an outward flowing graph. The graph consists of a common-sense color-coding scheme (red = danger/bad, yellow = caution, green = good, grey = neutral) and a variety of shapes (stars for endings, chat icons for conversations, squares for regular actions). Spill's graph is centered on the player and the actions committed by the player. Ryan used frames to organize the graph in terms of game-state (real world, and cognitive world). Ryan also separated the placement logic of his story elements into a node rules section. Ryan's graph resembles a mix of *broom, hidden, and opportunistic structure* [39]. There is a hidden structure as the player is able to listen into conversations (sub-stories) between different avatars. There is a broom structure because depending on the player's actions and movements in the story, this will lead to different endings. There is an opportunistic structure because what the player can achieve will unlock new possibilities in the story.

Tyson's Peak (Figure 7.1c) is a structured graph that uses containers to organize scenes in the story and separate story components. For example, some of the outside containers are used to organize NPCs, setting, and events. Within the events container there are sub-containers representing general event logic, locations and actions, dialogue, and animations. The logic, locations and actions, dialogue, and animations are all organized on a room-by-room basis. Inside the event frames, actions are described by a node and transitions between nodes are represented by an arrow. Moreover, there is color-coding to provide a visual reference between containers. Amy's graph illustrates the plot of the story in a linear sequence, however, due to the player's ability to interact with NPCs in an order they control there is a degree of nonlinearity. Amy's graph follows a *foldback structure* [39] as there are small shifts in the narrative due to the player's position, but the shifts eventually return to the original storyline.

Challenges with Representation

We investigate experiences authors encountered while using their graph. Although, using a graph *may* be easier than using a script when translating the story to Story CreatAR, it is also important to consider how difficult it is to create the graph representation. Furthermore, if these difficulties of creating a graph are known, there may be existing strategies or we may be able to present strategies for tackling these difficulties. This allows us to understand the pros and cons of using a story graph representation versus using a story script representation.

All authors struggled with how to represent items in their graph and knowing how much detail they should go into for describing those items. Ryan illustrates this difficulty when choosing how to represent his story as he states, "I feel like someone gave me base 10 blocks, and so now I'm like build the Mona Lisa". The biggest challenge Ryan encountered was surprising for him as he did not think the aspect needed to be added to the graph: the node (placement) rules. This stems from the broader challenge, which is finding a balance with how much or how little detail to include in a graph. Part of the difficulty with representing the story in graph form had to do with distinguishing what goes on a node (an action) versus a transition (a trigger). Amy stated "That was the hardest thing for me and I think what I ultimately came down to is that something in a box is something that is happening for a little, while an arrow is something that is a movement".

Spatial Considerations

Authors showed evidence of thinking in a spatial way, but still found they could better represent their graph spatially. Table 7.4 provides an overview of the similarities and differences on how authors thought of spatial aspects. When Ryan created his graph, the proximity of entities had meaning, "Generally, the entities that are clustered together are going to be the ones that are likely to repeatedly interacted with one

Techniques	**Amy**	**Eric**	**Ryan**
Rooms	Number of doors, categorical size, objects within, and shape	Number of doors, categorical size, objects within, and visibility to other rooms	Hallway as highest connectivity and largest size.
NPC Movements	N/A	Manually specified path	Areas of high/low traffic
Objects	In reference to doors and walls	In relation to other objects, prioritized	Visibility
Player Interaction	Inside/Outside a room, within a distance, in NPC's line of sight	N/A	Entering room
Proxemic Distances	Numerical values	Difficulty quantifying	Difficulty quantifying

Table 7.4: Spatial elements and spatial organization used in the graph

another". Ryan describes spatial rules by how objects (rooms, doors, windows, decorations) are placed, NPC trajectories, and player movements in relation to avatars and the environment. For instance, special conversations are placed in areas of low visibility whereas the hallway is the largest room with the highest connectivity, NPCs move in areas specified by high or low traffic, and the player can be caught if an NPC sees them enter a forbidden room. In contrast, Eric provides an example of what one placement may look like. In the example, Eric places objects in relation to other objects and provides low/high priority for their placement. For movements, Eric creates a path that shows where the avatar starts and ends the movement. Eric describes rooms in terms of its size (small/medium/large), objects present, number of doors, and how visible it is to other rooms. Despite Eric's manual placement of objects, he argues that it could be translated to another floorplan, "I think it could work in any kind of entrance I guess, because well, let's say that here's the entrance and in a wall that is close to the entrance in the left or right side there could be like the big mural that I mentioned in the word file...They could be placed in any order". Ryan and Eric had difficulty quantifying appropriate proxemic distances. This is illustrated by Ryan, "I don't have a certain distance in mind or anything. It's one of those things, just 'cause I'm bad at like measurements of that kind of stuff" and by Eric, "well, I know how close it is, but I don't know how to explain it". Amy provides spatial rules separate from the event logic. Amy describes rooms by furniture in relation to walls and the doorway (visible or not), number of doors, approximate (numerical and categorical) size of rooms, and the shape. Amy also describes player interaction with conversations by proxemic rules: inside/outside a room, within a distance, and in NPC's line of sight.

All authors felt they could be more specific on the spatial rules they specified in their graph. Eric would add more details on the rooms in his story, specifically where everything within a room is positioned/oriented, the measurements of important rooms, and categorical size of less important ones. Amy would actually redo the story and keep the setting specifications as flexible as possible. However, in regards to the current graph she would specify rooms by their relative size to other rooms and the number of doors per room, which she justifies by "I think for story flow and eavesdropping, 'cause it is about people moving through spaces distrusting each other, I think the number of entrances and exits are important". Ryan agrees that he could have better represented spatial rules in his graph, but he does not know how to do that. From this we can derive there are challenges with representing specific spatial information in the context of maps. Additional annotation could be useful within graphs.

Graph creation may help with creating a site-agnostic story as it encourages abstraction of story aspects (e.g., locative aspects, logical aspects, etc.), which can allow easier remapping of story content to the location. Related literature [69, 122] found that despite story graphs helping with representing spatio-temporal information, most story graphs suffer from visual clutter (e.g., too much information in the same space, crossing lines). We found the story graphs did help our authors represent spatio-temporal information, but they still encountered difficulty representing the many dimensions of story events and the relationships between them.

7.3.2 Author's Experience with Script

The authors used the script while creating their graph. All of the authors either added to or modified the script information during the translation to the graph. Ryan modified an NPC's functionality when he realized, "Admittedly, I'm looking at some of what I've written, and I'm like that's just not a good idea. Namely, I'm looking at Lapin Cadbury's special thing [strike functionality] and it just makes no sense". Additionally, the authors used the script while implementing a part of their story in Story CreatAR. Amy modified the script to simplify the proxemic rules between the player and conversations. Eric made a small change by adding dialogue line numbers to his conversations.

It was often time-consuming for authors to locate specific information in the script as the script lacked spatial relationships (e.g., the fireplace is in the main room, but not specified where in the room), and the script contained missing and incorrect details (e.g., Ryan referred to "clues" in the script abstractly and did not describe what the clues look like). The benefit of the script was the rich amount of detail it provided.

Spatial Considerations

All author's scripts describe placement in terms of spatial rules and in terms of space syntax terminology. Table 7.5 provides an overview on how authors thought of spatial aspects. It is important to understand how authors describe space in their script so we are able to support the spatial rules they describe and present the spatial rules in a way that is understandable to authors.

Ryan provides a limited spatial description of rooms, only considering how close the room is to doors and describes NPC movements as "walking around". Ryan describes objects based on whether they are on/against walls, their relation to other objects, and their spatial characteristics: hidden, traffic, visibility, and accessibility. Ryan provides several ways for players to interact: picking up and throwing objects (e.g., tea cups), listening to avatar conversations if within eavesdropping distance and not within the NPC's line of sight, and by entering a room.

Eric primarily describes rooms by size, distance (close/far) to other rooms, number of entrances/exits, and what and where furniture is located (middle of a room, centrality, and visibility). The player is able to interact by moving close/far to or entering a room and through voice commands.

Anna (script author of Tyson's Peak) describes rooms by their comparative size to one another, how connected they are, their shape (e.g., narrow), and the furniture

Techniques	**Tory**	**Eric**	**Ryan**
Rooms	Relative size, connectivity, shape, furniture	Categorical size, distance to other rooms, number of doors, furniture within	Distance to doors
NPC Movements	NPC movements not specified.	NPC movements not specified	Walking around
Objects	Accessibility, visibility, traffic	Middle of room, centrality, categorical size, visibility, connectivity, distance to room, right/left of room, relation to other objects	On/against wall, relation to other objects, hidden, traffic, visibility, accessibility
Player Interaction	Proxemics to a conversation, selecting response (method unspecified)	Distance to a room, voice commands, entering a room,	Throwing objects (not specified how), eavesdropping on conversations, line of sight, enter rooms
Proxemic Distances	Numerical values for distance	Close/far to a room, looking at an object	Eavesdropping distance

Table 7.5: Spatial elements and spatial organization used in the script

contained in a room (specified by accessibility, visibility, and traffic). Anna specifies player interaction by proximity (specific numerical distances) to a conversation and by selecting a response, however, Anna does not specify how a user would select a response (e.g., voice command or pushing a UI button).

In all scripts, there is a lack of specificity of where objects should be placed. For example, there is a couch and food/water bowls for the dog in Standville Museum. Are those items located along the peripheral of the room? In the center of the room? Do they all form a line? Evidently, the script lacked details on event and spatial relationships that were added to the story graph.

7.4 Developer Experience

Developers implemented a section of an author's story using Story CreatAR, added story specific events themselves, and made slight modifications to the placement. The developers were able to spend more time developing the story and they polished the story by adding additional story events/features. Additionally, as developers did not write the story, they were not able to fill in assumed details from the story script or graph that the authors may consider. This allows us to find details authors did not represent or were not clear about. I began the development by extracting key information to ease the translation to Story CreatAR: characters, animations, conversations, rooms, and objects. The other developer began by reviewing the recordings of the author creating the story graph and using the interface (as they were not involved), then they extracted events, rooms, and characters into lists separate from the story representation, created a linear form of the graph (as there were many paths that could be implemented), and then implemented the story section.

Developers made modifications to the placement for several reasons. One reason is due to our own underlying expectations: for example, a fireplace was moved to be against a wall, even though that was not specified. Another reason is due to the story representation being unclear on the intent of a proxemic/formation rule. For example, the Tyson's Peak script states that an avatar "Reacts with distrust": I asked Amy, who explained that, "NPCs would be more likely to turn their backs to the player when the player looks at them". Sometimes authors did not specify placements at all. For example, Ryan describes tables with tea and food, but does not state where they are located. If the spatial rule is unclear or nonexistent, the developers asked the author to clarify. Lastly, developers made modifications to the placement that they felt necessary. For example, there are several large furniture items (e.g., stalls, sinks, mirror) in the bathroom in Standville Museum, so the bathroom was moved to a larger room, even though Eric specified that it should be in a small room. Notably, the developer could have reduced the amount of props in the bathroom instead of changing rooms. However, props are specifically included by authors and unless otherwise specified, it is a likely assumption that the room would contain all the props. Therefore, the developer adjusted the room size as opposed to the number of props.

Developers made other decisions to make the story work. For example, to avoid custom development, developers utilized timer and traversal events to make it appear as one avatar is following another avatar. For example, Avatar X traverses to Conversation B. A two second timer elapses when Avatar X begins the traversal event. When the timer is finished, Avatar Y traverses to Conversation B. Some story-specific components that developers had to implement can later be integrated into Story CreatAR. For example, I created the ability to add different types of events: custom avatar animations that can either loop indefinitely or require a post-condition to stop it or play once, a conditional event (used to create simple if/then logic), and a dialogue event (plays automatically when this event is triggered). For example, a conditional event may be used to know if a player enters a room (story specific event logic). When the player enters a room, the conditional event is triggered and other events using that event as a precondition can be executed. A dialogue event differs from a conversation node as the dialogue plays automatically in the event sequence as opposed to waiting for player interactions. This may be useful for providing instructions to the player. Moreover, a heavily used (but not generalized to Story CreatAR) function was room-based triggers using manually placed colliders to determine when the player entered/left a specific room.

Developers also noted several areas for future work that are similar to author suggestions, which is unsurprising as the developer's suggestions are based on the author's story representations. Developers suggest the ability to specify rooms by number of doors, room dimensions (e.g., less than 12 metres), proximity to other rooms, and manually override which physical room is associated with a room name in Story CreatAR. Developers also wanted the ability to differentiate between a hallway and a room. Developers wanted to place objects against/on a wall, in relation (distance/orientation) to other objects, and based on other spatial characteristics (*visibility*: how much a user can see from one location, *accessibility*: how accessible the location is, *traffic*: how likely people will use the path). To increase efficiency, developers wanted to move multiple avatars in a single traversal event. Developers also wanted to move an avatar to a room (as opposed to just a conversation node). Additionally, developers suggested having text as a story element. They wanted to have a set of events loop. They also wanted a template for organizing story content to ease the translation to Story CreatAR (e.g., extracting characters, conversations, rooms, events, etc.).

The developers presented their implementation of each part of the author's story through a video recording of the experience in VR. The authors feedback ranged from spatial considerations, author realizations, conversation triggers, implications of timing, and considerations of the medium. Amy and Eric found the many changes to room properties (larger size, proximity, object position interpretation, and object formation) the developers made to be agreeable. Amy demonstrated her support for the developer's decision to make rooms closer together by saying, "from a screenwriting point of view, I think the size of each individual room is less important than the proximity so you can feel like you are in one cabin space". Amy also had general positive feedback in terms of placement and how it affects the storytelling, "the placement of the bed looks good, and is especially effective as it forces the avatars to be closer to the door and thus easier to eavesdrop on". Eric admired the F-formation of the clues used in the realization of his story, "in this room, I imagined the sculptures to be like in a line if that makes sense, but I am thinking I really like these positions". Ryan noticed that he did not include some details necessary for the developers as he states, "I realize I work well with general terms and I am working to get better on specifics". In terms of spatial aspects, Ryan corrected the number of doors for Fokthipur's room as it should be only one. In addition, the proxemic distance cutting off a conversation was jarring to Ryan and he suggested that the volumes should just get lower the further away a user is.

7.5 Story CreatAR Features

7.5.1 Quantitative Summary

Table 7.6 shows a quantitative summary of the features used by the authors in Story CreatAR. Eric's story segments for the graph and script implementation contained the same amount of characters (part of story elements count) and differed in the amount of objects as the two story segments took place in different rooms in the story. In the story segment for the graph, Eric created all possible events (two conversations, one timer, one traversal) in the story segment. In the story segment for the script, Eric began the story implementation at the beginning of one path and included two events (conversation and avatar traversal), however, he could have extended the story implementation by adding more events. Similarly, Amy created the same amount of characters in each story segment. In the story segment for the script, Amy included one out of seven objects that were specified, rather than all seven that were included in the graph segment. She created similar amounts of events for both story segments. In Ryan's graph segment, he created an avatar for each character in his story (five total) and in the script segment he created only two characters to simplify the amount of story elements he had. Ryan had a similar amount of objects in his story as both segments involved the same locations. Ryan created more events in the script segment as he was experimenting with the interface, but most events were not used to progress his story.

Ryan was unique in several ways. He was the only one to use groups and had a positive experience with them. In addition, since Ryan was having difficulty with events, he focused more on placement rules and was the only one to experiment with a facing rule to trigger conversations as opposed to distance rules. Perhaps due to the flexible nature of Ryan's story, he constrained the story by rooms the least. In comparison, Amy heavily relied on room placement as she used room rules most often. Despite the lack of availability for a "player" to participate in a conversation, Eric created an avatar as a placeholder for a player so they were able to participate in conversations.

Story Component	Eric Graph	Eric Script	Amy Graph	Amy Script	Ryan Graph	Ryan Script
Events	2	1	2	3	2	8
Conversations	2	1	5	4	2	5
Default Attribute	9	0	4	0	17	11
Created Attribute	0	0	1	3	1	4
Room Attribute	0	6	12	9	2	0
Story Elements	13	8	15	9	9	14
Groups	0	0	0	0	3	3
Refresh Placement	4	2	0	12	0	0
3D Viewer	3	7	1	0	0	0

Table 7.6: Number of Story CreatAR features used by authors.

7.5.2 Traversal and Timer Events

Authors used the interface with their script and with their graph and created traversal and timer events. Authors had difficulty creating global events in Story CreatAR that depend on each other (e.g., timer event as precondition for traversal event) and due to lack of editability (feature was implemented as proof-of-concept rather than for robust use, e.g., events cannot be edited once added), it required events to be added in chronological order. Specifically, the authors had difficulty finding and using traversal events causing confusion and loss of time. When creating traversal events, authors were confused by the "Go To" dropdown as a lack of options were available due to not having the necessary story locations created beforehand (i.e., a conversation node the avatar is involved). They were looking to have avatars go to rooms, but could only get avatars to go to conversation nodes. We provide conversation nodes as the primary organizing elements as the initial stories implemented with the tool (The Lost Child, Tyson's Peak) use conversations as primary organizational structures. Authors wanted avatars to go to a room instead of a conversation node, so were confused when their created rooms were not options. Creating timer events was easier than traversal events. However, authors discuss the challenge of coordinating event timing with other events. Some issues are due to coordinating a continuous experience such that all events line up with each other. Other difficulties are due to reliance on how long it takes an avatar to move, which varies depending on the map, shown by Amy while creating her graph, "You don't know how big the space is, so you don't know how long it takes for the avatar to get to a room". In Story

CreatAR, this is not an issue as authors can create a precondition specifying to wait until the traversal event is completed (i.e., avatar has reached the room/destination). This difficulty with timing is not as much of an issue in film as they can use cuts to break up a seemingly continuous experience. Events are ordered using preconditions. All authors had difficulty understanding and using preconditions effectively. Though, all authors later understood how to use the preconditions and desired more options (e.g., conversation ends).

7.5.3 Triggers and Group Formations

Authors were able to correctly interpret and use proxemic triggers in Story CreatAR. Amy complimented the simplicity of creating distance triggers, "Cool! That was easy! I actually really do like how you set the proximity triggers within distance and the range, that's really easy to use". However, Ryan and Eric had a difficult time specifying numerical values for the distance. This is illustrated when Eric said, "I know how close it is, but I don't know how to explain it". Authors mostly referred to the orientation-based proxemic rules in terms of the ability to "look at" something else. In Story CreatAR the triggers were described using the abstract terms "Actor" and "Subject", however, it may be easier for authors to understand terms such as "Player" and "Conversation". All authors showed desire to describe proxemic relationships with respect to a room, although this feature was not available in Story CreatAR. For example, authors were trying to trigger an event (e.g., conversations) by being within/outside a room. In addition, authors expressed interest in the ability to have always true triggers, combine multiple triggers using an "OR", the ability to express interactions between players and the spatial configuration, and triggers based on cardinal direction (North/East/South/West).

In contrast to some other spatial relations, group formations were uniformly used, understood, and liked. Authors liked the circle F-formation provided by Story CreatAR, but also desired additional formations (e.g., ones that include props, semi-circle formations) and the ability to specify custom formations through a drag and drop grid interface. However, authors showed limited use of F-formations in their graph, which could indicate that it is not natural for authors to think in this way.

7.5.4 Conversations

Authors had difficulties navigating and using the Story CreatAR user interface to create conversations. Notably, the authors had difficulty matching the dialogue line names presented in Story CreatAR (e.g., "Bob 1.1") to their story script, mostly due to unlabeled dialogue in their script. Authors liked the ability to specify dialogue volume settings and background music. They also thought Story CreatAR would benefit with having additional avatar interactions (e.g., folding arms, shrugging, turning) as it creates richer conversations and breaks up static movements. For example, an avatar may talk to another avatar, pace back and forth, then talk again. Ryan and Amy were able to correctly interpret the meaning of the proxemic distances (intimate, personal, social) used to describe how closely avatars are arranged in conversation and chose this proxemic distance based on the relationship of characters in the conversation. However, Eric incorrectly interpreted them as referring to how many avatars are present in the conversation. Story CreatAR could support the correct interpretation by providing a visual representation of what each distance would look like and providing a definition when hovering over each distance.

Authors had difficulty with the connection between the compound story elements screen and conversation node feature (which is one type of compound story element) in Story CreatAR. In Ryan's case this resulted with a lack of interaction with the compound story elements screen (adding conversations) at the start of his experience. Amy also had difficulty creating conversations based on the avatar placement dropdowns. For example, Amy placed all avatars in her story in "initially placed avatars" (appear at start of game) and was confused when she was unable to place any more avatars as "initially placed" (as they were already placed somewhere else at the start of her story).

7.6 Space and Placement

7.6.1 Misunderstanding of Spatial Analysis Concepts

Authors had difficulty using and understanding spatial attributes. Part of the difficulty may be a result of the difference of what they expect to happen when using the high-level attributes provided in the interface and what actually happens, the difference between all possible spatial analysis characteristics and the ones we provide, and that they have not used spatial attributes previously, so the value of using them is unknown. Authors interpretation of the space syntax terms can be misdirected for a number of reasons. First, the space syntax terms do not account for furniture in the environment, but the authors expected that it would. Second, they are basing their interpretation of the space syntax characteristic (openness, visual integration, visual complexity) from the high-level term itself. Despite not completely understanding the space syntax characteristics, authors still used them based on their understanding. For example, Ryan thought "[of openness as] assuming limited amount of things around it", "visual complexity does that just mean where there's a lot of stuff?", and "Visual integration, is that how similar something looks to it's environment?".

High-level spatial attributes were also commonly misinterpreted as the names could have multiple or overlapping meaning. For example, Amy explains, "So all of these places [spatial attributes] (open area, closed area, central area, uncentral area), those all sound like room-to-room locations to me, whereas hidden and easy to find could mean a variety of things". Other ways authors suggest to understand the space syntax characteristics was through the comparison to other space syntax characteristics, considering a simple definition of them, and understanding the extreme cases of it.

Although the F-formation and proxemic theory is arguably less complex, these terms were still subject to the same misinterpretations. For example, Eric explains, "I picked social because Max and Detective are talking to each other", however as the two characters are father and son, personal may be a better suited distance.

This misunderstanding may have also been formed while they tested the placement in the interface (e.g., by viewing only one map, having only one version of the placement, etc.). This is shown by Amy, who experimented with the placement using visual integration and noticed that high visual integration placed the bed by the door in one version of the placement and therefore reduced the visual integration value. Notably, the high-level attributes designed to overcome the complexities of the low-level attributes had the same misinterpretations. For example, Amy emphasizes that "Hidden" and "Easy to Find" could mean a "variety of things". This could be due to the names of the high-level attributes being unclear on what exactly they mean without providing additional context (e.g., does centrality mean centrality of a convex space or the entire map).

Although, the authors also were able to achieve placement techniques they wanted across different floorplans. For example, Amy experimented with the placement of her story elements across different floorplans and found, “Oh I like that much better. Perfect actually, I love that, so I like the way the system has just clustered them”.

7.6.2 Rooms

Author’s confusion with rooms started at the image of the floorplan in the rooms screen. As it was color-coded, they thought all the rooms were already created for use in Story CreatAR. Authors became confused with what the term “room” refers to. They wondered if it is a room in the traditional sense (e.g., bedroom) or if it it is any convex space. Unlike Amy and Eric, Ryan did not use rooms as a way to organize his story components. Instead, Ryan’s graph was organized by game state.

Authors described rooms in many ways. Size of a room was described based on categories (small, medium, large), exact room length and width, and in comparison to other rooms (e.g., bedroom is smaller than living room). Moreover, thinking in terms of rooms appears to be unnatural by authors as illustrated by Amy asking Ryan, “Did you feel like the size of any particular space would be important for the storytelling?” and Ryan responding, “I didn’t to be entirely honest”. All authors seem to think it would be useful to specify the proximity of rooms to other rooms or room features (doors/windows). In addition, authors describe the number of doors per rooms, the room shape (e.g., round/square), its visibility to other rooms, and windows for access to light. Amy and Ryan were trying to get precision out of Story CreatAR by classifying a hallway as the largest room with the highest connectivity. Lastly, authors would prioritize different room properties over others.

A large portion of the space and placement section of the affinity diagram is dedicated to rooms. All authors use rooms as an important part for structuring their story. Eric and Amy specifically used rooms as primary organizational structures for the events in their stories and described many room properties. For example, conversations would take place in specific rooms. Ryan used rooms to structure different states of his story.

7.6.3 Positioning

Authors were able to specify the position of story elements using the attributes provided to them. Authors used both the default attributes and created their own. Ryan and Amy illustrate several examples of translating their story representation's spatial rule into one of the default attributes. For example, Ryan assigns an attribute based on a character's personality, "Bultilda is a very confident, self assured, warrior and doesn't care if people see her, so she is in the open, easy to find". In addition, Amy translates "on the other side of the wall from the hallway" to "hidden". Ryan and Amy were able to create attributes using all three space syntax characteristics. Amy also iterated on her placement by adding an attribute, viewing the placement on the map, and modifying the attribute until she was satisfied with the placement.

There was a struggle for authors between creating an attribute with a meaningful name and using the high-level attributes provided to them. Ryan used the *create an attribute* feature in an unexpected way: to create placeholder labels to specify what he would like it to do as it is not possible or not apparent how to do it. He used the labels to indicate that objects have a hierarchical relationships and placement that he could not specify in the interface (e.g., place one object on another object). Ryan creates an attribute called "Central doorway" that uses no space syntax characteristics and says "so my hope is that'll [the attribute] just assign it to there [the story element], but I don't think it'll show it here [the placement map]". This use of the attributes translates into spatial features that the authors would have liked or wanted and therefore can be incorporated in future work.

Authors had difficulty to maintain flexibility in their position descriptions. Authors repeated the desire to manually move objects to locations they had in mind. For example, Eric wanted to reference his initial manual placement, "I remember at the very beginning of the story I drew the map and I numbered the rooms because I just imagined the whole story in that order. I would like to follow the pattern that I chose". Similarly, Ryan stated, "it would be nicer if you could see a more obvious use of the mini-map (click and move objects on the 2D model even if it is a small grid)". Eric was uncomfortable with having flexible placement as shown by him saying "I had like a mini heart attack" when reapplying the spatial rules to view a different placement. Amy emphasizes the importance of trying to maintain flexible placement, "One of the really great things about the Story CreatAR system is that it does allow for a story to be realized in a variety of spaces and you don't want to counteract that flexibility". However, there was a tension between wanting to manually place objects and trying to create flexible placement. As illustrated by Amy, "If I were just writing a screenplay for fun, that was never gonna be passed on to anyone I actually would design the space, like I would map it. However, with Story CreatAR in mind and that amazing flexibility that it has to be adapted to different spaces, I wouldn't [do manual placement]". Only Amy viewed the placement of her story elements across multiple maps and Eric visited the 3D preview the most. Ryan thinks the 3D preview is very important, however, it should be embedded within Story CreatAR itself rather than a new scene in Unity.

7.7 Summary

The authors all varied in their reliance in creating the graph and using the interface. They all produced different types of graphs and described placement techniques in both their graph and script. Ryan and Amy found the decisions the researchers made for story content placement to be agreeable, however, Ryan corrected one spatial aspect (number of doors in a room). Our authors often misinterpreted spatial analysis concepts, however, the authors still found utility in using the spatial techniques. Some authors structured their placement using rooms as an organizational structure. Authors were able to derive attributes of the story content to derive placement values. Authors further pushed the spatial capabilities by desiring unsupported features.

Chapter 8

Discussion of Authors using Story CreatAR

8.1 Introduction

This section discusses authors understanding and use of spatial analysis techniques. We emphasize that authors misunderstood the spatial analysis concepts and it is not natural for authors to think in terms of multiple sites, thus we provide potential solutions to these issues. Additionally, we identify areas where we can extend the spatial analysis support in Story CreatAR. Furthermore, we discuss insights on how authors created their story graph and used the interface.

8.2 Spatial Analysis Insights

Authors used a wide range of spatial rules both in their story representations and while using Story CreatAR. Authors had mixed experiences using the spatial rules. Amy had a positive experience with the room association screen, as it provided her with a spatial arrangement she did not consider. In addition, Amy was experimenting with the placement of her story elements across different floorplans and found, “Oh I like that much better. Perfect actually, I love that, so I like the way the system has just clustered them”. This kind of response is undesirable for a site-agnostic story, as Amy finds the placement is suitable for one floorplan and not another, but is content with the placement being suitable for only one of the two floorplans. Eric also provided positive feedback regarding the creation of stories as he believed using Story CreatAR, he could create “any kind of story you want” due to the extensible nature of the content. However, Eric also had negative experiences as he worried about changing the position of his story elements using the *reapply rules* option and he worried about how to represent internal monologue for the player. This could indicate an emotional barrier for authors as once they find an acceptable placement, they may not want to alter it. Ryan found the process more challenging than anticipated. This led Ryan to distrust Story CreatAR's suitability for stories like his own, highly dependent on player interaction as the only player interaction available in Story CreatAR was the proxemic triggers for conversations.

This section discusses possible improvements for Story CreatAR or an alike tool: how to overcome the complexities of authors using spatial analysis concepts, how to encourage authors to think about placement across multiple floorplans, and how to extend the tool to provide a more suitable set of spatial analysis concepts and techniques.

8.2.1 Need to Overcome Barriers to Spatial Analysis Understanding

There are many tools present in the literature that provide space-adaptive functionality. Some of these tools provide specialized considerations (e.g., choose a large room for higher presence and usability) [120, 121] that impact the immersivity of an experience. However, these tools do not provide a way for nontechnical users (e.g., story authors) to understand and appropriately use these considerations. Several tools [55, 41] use techniques to generate a space-adaptive experience on-the-fly. Despite the lack of technical knowledge required for these tools, they do not consider the whole floorplan in placement (i.e., their space understanding is limited to what the depth sensors can see, which are attached to the user) and this may result in continuity issues. For example, an avatar may be supposed to walk to a bathroom, but since this room has not been encountered by the player yet, the system does not "know" where this room is.

We find an overwhelming need to aid authors with understanding spatial analysis concepts and supporting how to use them effectively. Despite the spatial attributes being discussed on an ongoing basis with the authors months before the study, they still had trouble arriving at correct definitions. As found within the Misunderstanding of Spatial Analysis Concepts section, authors misinterpreted the meaning of the individual space syntax characteristics similarly based on the term. This is unsurprising due to the technical names for the low-level space syntax characteristics (openness, visual complexity, visual integration). The meaning they derived on the word alone, drives their use of the attribute. As we are not experts of space syntax ourselves, we attempted to explain the spatial characteristics using simple definition and metaphors of extreme cases.

As found, the high-level spatial attributes were also subject to the same misinterpretations. It could be that adding the high-level attributes confused authors, given that many attributes had seemingly overlapping meanings and short names that could be interpreted in several ways. Instead of authors learning the attributes and their meanings, authors learned by exploring the effects of different combinations of attributes on the floorplan. These results for the high-level attributes are similar to results with using space syntax characteristics, as Raford [44] finds there are significant barriers to properly use and understand space syntax characteristics.

The authors provide several suggestions for how to make the space syntax concepts more comprehensible: provide definitions in simple terms, provide and explain examples of different use-cases of the space syntax characteristics, show possible placements simultaneously across multiple floorplans or variations of the placement across the same floorplan, provide an immersive walkthrough, and allow the system to learn by authors demonstrating their desired placements. I showed authors the output from depthMapX shown in Figure 2.2, which provided context on how each individual characteristic classifies a space. Story CreatAR allows authors to view different placements of their story elements given a set of spatial rules, both on different floorplans and adjusting the rules for a floorplan, but it does not show multiple variations of the placements concurrently. Authors are able to test their story in an immersive medium (VR), but this currently involves multiples steps and deploying through the Unity interface. Moreover, a 3D view is currently accessible to authors by viewing the scene in Unity, however, we would like to make this accessible within the Story CreatAR UI. We would like to allow deployment from within the Story CreatAR interface to reduce technical barriers.

As one solution to overcome the misunderstanding of spatial analysis concepts, Eric and Ryan suggest a programming by demonstration (PBD) [89] interface for specifying spatial rules. Eric suggested this type of demonstration when he specified object's placement in his graph. Eric considered the graph as if it were the physical environment and placed objects roughly where they would appear in relation to other objects, rooms, and events. Ryan argues that a PBD interface simplifies the use of attributes as he states, "it could actually make it easier to add the attributes because then when you click and drag and you place it [story element] somewhere, you can be like okay generally this is the kind of location I want it to be". In addition, Amy hints at the utility of this type of interface as she said if she were not using Story CreatAR, she would place items physically, however, with Story CreatAR she is trying to keep the placement as flexible as possible. A PBD interface does not require authors to use and understand the spatial attributes. Instead it offers a more familiar way to place objects based on their imagination. Spatial analysis techniques will still be useful with this interface as they can be used in the backend to analyze the types of spaces suitable for author placement and to categorize these types of spaces with spatial characteristic values. However, there are some challenges and weaknesses of a PBD approach. This approach requires that the floorplan they are using is representative of other floorplans the author may use (e.g., a given floorplan may only have a subset of different spatial locations). Manually placing objects does not allow authors to define placement abstractly, which does not provide insight on the intended placement. Thus, authors may not fully understand the spatial attributes when used in this way. This could be an issue for placing objects in different or unknown locations. For example, multiple spatial attributes may be used to describe the placement, but maybe only a few spatial attributes actually match the author's placement criteria. Furthermore, in a PBD approach authors have to precisely consider relationships between objects, events, and the spatial configuration.

8.2.2 Encouraging Authors to Think of Deployment in Multiple Sites

A critical challenge for locative narratives is that the content needs to be mapped to different locations [66, 67], which causes challenges for authors designing content that can be played in multiple environments [73, 84, 94, 98, 103]. One challenge for creating locative media content in a site-agnostic manner is a lack of control for authors as they can not specify exactly where they want objects and events to go. Furthermore, the authors encounter challenges with the medium of AR itself as players have high agency: players can position and orient themselves how they want, and choose their own trajectories. However, authors are able to control progression of the story and choices the viewer has available to them.

One indication that authors needed more encouragement to think in a site-adaptive manner was due to authors expressing the desire to manually place content or precisely define the spatial rules as shown in the Positioning section. Authors wanted to manually position objects and explicitly select rooms. Eric wanted to specify precise definitions of the room size (e.g., 12 meters wide by 10 meters long) and worried about generating a new possible placement as he thought he may "destroy" his current scene. This indicates that Eric was focused on making one placement effective and not thinking in terms of how the story would appear in multiple sites.

Showing multiple placement options simultaneously, as suggested to help combat the misunderstanding of spatial analysis concepts, may equally help encourage authors to think of placement in terms of multiple locations. A compromise between providing specifics to authors and thinking of multi-site placement may be providing common features of spaces that authors can consider when creating their story. For example, most buildings are likely to have a front door, a washroom, windows, etc. This could be further specified if the author was familiar with the types of environments suitable for their story. To illustrate, an author may design a narrative to be experienced in peoples homes. Therefore, they could expect to have a kitchen (e.g., fridge, oven), bedroom (e.g., bed, wardrobe), living room (e.g., couch, TV) etc.

8.2.3 Extending Spatial Analysis Support

In addition to the basic space syntax (openness, visual complexity, and visual integration), proxemics (orientation and distance triggers), and F-formations (circle) support provided in the interface, authors desired other spatial analysis support as shown in their scripts, story graphs, and ideas expressed when using Story CreatAR. Here we present how we could support spatial rules our authors desired with spatial analysis techniques, but further investigation is required to find a comprehensive set of spatial attributes.

Using isovists already generated by depthMapX, Story CreatAR can extract the values for *minimum isovist radial*, which detects obstructions (for an empty floorplan that would be walls). Low values of minimum isovist radial can be used to place an object against a wall. *Visibility field* (isovist intersections) [35] can be used to determine where objects/NPCs/player are visible from. *Isovist drift magnitude* can be used to provide a sneaky path.

In addition to the isovist-based characteristics, Story CreatAR should support more room-based properties. Currently, Story CreatAR uses AFPlan to calculate convex analysis as opposed to using depthMapX since AFPlan uses machine learning algorithms to automatically detect rooms, while depthMapX requires manual input of the different polygons (rooms). AFPlan automatically performs a convex analysis which is used to identify edge points for a room. These points can provide relative room size, detection of whether a movable item is inside/outside or entered/left a room. If provided the appropriate architectural symbols, AFPlan can be used to detect where doors and windows are as well. This can be used to determine light sources and the number of doors per room. The number of doors per room was an important property for Ryan, who corrected the number of doors a room should have when watching the VR output done by a developer. These room properties can be used in combination to determine a room's relativity to a door. We could also integrate depthMapX's convex analysis to produce a justified graph (unavailable in AFPlan), which represents how many steps need to be traversed to reach each convex space. The justified graph can be used to calculate a room's relativity (proximity) to other rooms, identify directly connected rooms, and determine a room's accessibility. We may identify a hallway as a room that has a rectangular shape, high connectivity, and a large room size, however this would be unreliable and require manual overrides. Story CreatAR could allow authors to specify the generic shape of a room (circular, rectangular). We may be able to determine this using spatial analysis by generating the perimeter from the corners of the rooms provided AFPlan. We may also use a room's position, dimensions, and relative positions of doorways to determine specific walls of a room in relation to a door (e.g., paintings should be on the left wall).

We can incorporate agent-based analysis to identify high/low traffic areas. Our authors suggesting traffic is unsurprising due to the large body of literature surrounding traffic evaluation in space through other tools like NetLogo [7]. Cardinal directions (North, East, South, West) could be integrated as a spatial property used for event triggers. Cardinal directions of rooms can be determined by inputting a floorplan with known real-world orientation and using openCV [18] to identify the centroid of a room. The direction of a vector between the centroid and any point in a room determines the cardinality. In addition, the centroid helps identify the middle of a room. Furthermore, ProxemicUI is being used to provide relative position and orientation rules between the player and conversations entities and for forming F-formations. However, we can further exploit the power of ProxemicUI through different entities (e.g., rooms, story objects, story events), different formations (e.g., lines, semi-circles), different ways to combine rules (e.g., AND, OR, XOR), and more complex rules. Authors also noted their concern for the proximity rules triggering dialogue when the avatar/conversation is behind a wall, which reduces the realism of the experience. We can ensure that the viewer and conversation are contained within the same isovist to ensure there are no issues with the conversation not being in the viewer's line of sight.

There are also a few spatial rules that our current suite of spatial analysis techniques do not support. Space syntax does not detect objects being on top of other objects. However, to place objects (e.g., a note on a desk) in Story CreatAR, we can bind the assets together. Additionally, we could support gaze detection by using the eye tracking available in Mixed Reality Toolkit [92]. This can be used to detect if an event is in a player's line of sight.

For deployment in AR, some authors may want to combine virtual objects and physical props for their story. In this way, we may want to support generation of physical objects using and assigning labels in the same way story elements are placed. These props could include room dividers to partition a large empty space so that it better matches the author's desired floorplan specification. A future extension of this could be generating a desired floorplan based on these specifications, which could be experienced in VR or recreated in a blank space in AR. We may also consider the reuse of physical space during a story, which may be required for a large story in a small space. For example, perhaps there are branching paths where each path introduces a new room. This would be a suitable situation for reusing the space. However, there could be a loss of spatial cognition for story understanding depending on how much of the space is reused, for what story sections, and how large the space is.

To better understand how authors place objects in a particular space, think-aloud sessions could be used, where authors manually place their story content and describe the factors used in making these decisions. This informs what spatial characteristics authors want and how to encourage them to think flexibly.

Lastly, we also want to provide clear ways for authors to apply multiple spatial rules and to prioritize them. For example, we may allow authors to select all the spatial attributes they want for a story element instead of selecting one at a time. When authors select the attributes for their story, they can also specify a priority from 1 – n (high – low).

8.3 Authoring Process Insights

8.3.1 Introduction

Authors had difficulty with planning and creating events in Story CreatAR. We also found that authors created their stories using an iterative process (e.g., modified the story when creating the graph or when using Story CreatAR). We find that it may be useful to support authors in creating a story graph representation, however, there are challenges with providing a set of standard guidelines.

8.3.2 Difficulty with event relationships

Prior research [36] suggests that it is difficult to plan for events in a locative narrative. This is seen through the use of Story CreatAR as authors had difficulty creating and using traversal and timer events. Authors found it difficult to distinguish between events (e.g., conversation) and event triggers (e.g., player walks into room) in the graph. When Ryan watched the developer approach he realized he does not understand how long timing should be. Our event model follows the less common approach for creating interactive content: a planning technique rather than a conditional branching technique [95]. It is even more difficult to plan a timed event based on travel time in an unknown location. Thus, the issue of planning for events in a locative narrative still remains. However, we provide insights on how using preconditions as event triggers are confusing for authors and ways authors suggested to help plan events.

Specifically for Story CreatAR, in future work we envision providing authors with an event preview that shows the order of events (e.g., timeline) and a visual preview to show what the individual event does. We also envision increasing the amount of precondition options (e.g., when a player enters/leaves a room, when a voice command is said, when an animation has occurred, etc.), renaming "Traversal" event to "Movement" event, providing an option for type of path choice (e.g., high traffic path), and providing rooms as an option for where an avatar may move.

8.3.3 Iterative Authoring Process

During the creation of the story graph and through the author's use of Story CreatAR, authors added more details or revised/improved existing details in their story, specifically regarding space. This may indicate that without prompting, authors would not naturally describe story settings and object positions spatially. Amy describes this iterative process as expected for filmmakers: "that happens in filmmaking because you never do exactly- unless you're Hitchcock- but he was very anally retentive- you never do what is exactly on the page, that's the process, that's completely understood". Specifically, creating the graph led to editing the screenplay, and timing events often required more precision (e.g., specifying exactly how long an avatar should wait for). Furthermore, this shows that Story CreatAR is not simply used as a production tool, but also as an editing tool and must provide editing support. We could provide a summary of the knowledge the user has acquired based on their choices as done by Mobile Urban Drama [65]. We could show a viewer entity and allow the author to bring the viewer through different events, and representing what knowledge the user knows and does not know.

8.3.4 Supporting Story Graphs

Graphs are a common way to represent stories, but creating a graph that accurately represents an immersive AR narrative is difficult as authors need to consider a continuous, 360° experience. StoryPlaces [67] is a tool for locative narratives that represents the story as a graph where events in the story are represented as nodes and locations as conditions. This allows the narrative content to be easily remapped to new locations, but it may lead to breaks in continuity due to discrete locations being mapped. For example, this may work in an art exhibit where the experience has separate sections, but it will not work for a haunted house as it is designed to be one cohesive experience.

Although there are indications that supporting a graph representation that suits Story CreatAR would be helpful (e.g., Ryan lacked aspects of the graph required in the Story CreatAR interface such as dialogue lines), there are also challenges in providing appropriate guidelines. As we only looked at three graphs, we do not have a standard graph, but only commonalities and differences. All authors created different graph forms which were reflective of the type of narrative they created. Moreover, authors provided relationships in their graph applicable to their story. Some of these were similar (e.g., describing rooms by number of doors), however, others differed (e.g., placing objects in relation to others). All authors struggled to differentiate between cause and effect, and to represent time-based and spatial aspects of their story, perhaps due to it being unclear in the script. It may be helpful to clearly divide these different aspects using multiple graphs linked together. For example, we could represent placement structure as one graph, story logic in another graph, and time-based structure in another.

8.4 Limitations

Our authors have been collaborators on the project for over a year, which means they have been exposed to and influenced by our research questions regarding the effect of using spatial analysis concepts on storytelling. This may manifest in how the authors describe space in their story representations and how they think about space during the authoring phases. For example, authors described space using space syntax characteristics (e.g., visibility, traffic), between and within room constraints (e.g., one door), and proxemic relationships. These concepts were learned by the authors through our discussions. Moreover, our authors were able to ask questions throughout the creation and implementation of their story. We do not expect authors using Story CreatAR to have access to this level of technical support.

Further, the design of the authors' graphs may have been influenced by our example of "The Three Little Pigs" in terms of the framing concepts (boxes, arrows, frames) and their representations (entities, transitions, locations). All authors used boxes, arrows, and frames to represent their story. Eric and Amy used frames to represent rooms in their stories, and Ryan and Amy used boxes and arrows to represent causality in the story. However, the authors still produced vastly different graphs. As a result, it is difficult to extrapolate to a common graph format for Story CreatAR authoring.

A challenge that remains is attracting and directing the viewer's attention [47]. In traditional narratives, writers have control over what the viewer sees. However, in 360-degree narratives, the viewer controls what they are looking at and could potentially ignore the narrative. Story CreatAR may consider using spatial analysis techniques to attract viewer attention. For example, we could put objects in high visibility areas so they are more likely to look there. However, this becomes even more challenging for AR versus a 2D movie or theatre experience as the viewer can explore the story region freely.

Moreover, our study examines three film and media studies students as authors. This has several implications: we have not seen authors of nonacademic backgrounds, two of the three authors are novices, and perhaps a different background of storytelling may lend to different results with our tool. With only three authors, we are not able to generalize our findings, but we can derive meaning and future directions for Story CreatAR. This leaves as future work to implement these suggestions, test with more authors with different stories to help find a comprehensive set of spatial techniques, methods to understand them, and how to encourage authors to think about placement in a more flexible way.

8.5 Summary

This section presented how authors understood spatial analysis techniques and how effectively they were used for a site-agnostic experience. We found that authors needed more support for fully understanding the spatial analysis techniques we provide in Story CreatAR and suggest to do this using a PBD interface. We also found authors needed encouragement to think of placement in a flexible manner, which we suggest to do by using multiple placements presented simultaneously. Additionally, we discuss how the spatial analysis tools and techniques we use can be extended to support spatial rules authors desired, but were unavailable in the interface. Furthermore, we discussed the difficulty authors had with planning for event relationships, Story CreatAR should support an iterative workflow, and Story CreatAR should provide recommendations for authors in creating their story graphs.

Chapter 9

Discussion

9.1 Introduction

This chapter reinforces the motivations for Story CreatAR and how it addresses issues faced by immersive locative AR narratives. Story CreatAR uses spatial analysis techniques to abstract story content from it's location, adapt the story to multiple locations, and it incorporates RocketBox Avatars and custom assets to create a high-fidelity immersive AR experience. We evaluated Story CreatAR to investigate how authors understand and use spatial analysis techniques. I present possible extensions to Story CreatAR including narrative-spatial mappings derived in our design activities and integrating natural movements for avatars (e.g., avatars can move using sneaky or central paths). I detail current work, which uses the resulting experience from the Story CreatAR evaluation generated for VR and adapts it to an immersive locative AR experience. I propose directions for future work including a structured study that compares different placement techniques at two locations (one with high predictability of spatial analysis techniques and one with low). Lastly, I present an experience visualization to help inform authors on how players experience their narrative, so they can adjust story content to optimal placements based on user experience.

9.2 Story CreatAR Motivations

9.2.1 Tool for Creating Locative Media

One motivation for this project is creating a generic immersive AR *locative media* tool. As described in the background, there is a lack of generic tools for creating locative media content. StoryPlaces [67] is one generic locative narrative creation platform, however, there are some limitations to the tool which are addressed in Story CreatAR (e.g., not supporting automatic adaption of story content to new locations). StoryPlaces and Story CreatAR have key similarities and differences.

- *Aim of tool*: StoryPlaces is designed as a system for creating site-specific locative narratives. Story CreatAR is designed as a system for dynamically adapting locative narratives using spatial analysis techniques.

- *Workflow*: Both Story CreatAR and StoryPlaces provide an author-facing interface. Authors create their story using StoryPlaces, however, in Story CreatAR we imagine the conception is external to using our tool as its main benefits is for placing story content. Both tools allow an author to test the story (by reading — StoryPlaces, or 3D preview — Story CreatAR) and make modifications or allow others to view the story (2D plane view — StoryPlaces, or spatial 3D holographic view — Story CreatAR).

- *Guiding the viewer*: StoryPlaces allows authors to guide users to locations using hints, which can be descriptive directions or a marker on a map, whereas Story CreatAR provides authors with spatialized audio and avatar animations (movements) to direct the viewer's attention. Story CreatAR may benefit from incorporating a guiding trail which was externally implemented in my current work.

- *Story experience*: Stories created by StoryPlaces are presented on a 2D webview, however Story CreatAR produces immersive AR/VR narratives.

- *Story events*: StoryPlaces provides authors with simple modifications to variables and conditional statements for triggering events and Story CreatAR provides event preconditions that wait for its preconditions to be true before executing. Story CreatAR may benefit from providing authors access to simple variable operations and providing conditional statements rather than preconditions so authors have more control over changes in story state. For example, once an author says a voice command (e.g., "Choice 3"), a variable is set that is used by a conditional statement to provide the appropriate response (e.g., "Error, please try again"). Unlike Story CreatAR, StoryPlaces provides minimal support for triggering story events through viewer-based proxemic rules.

- *Remapping story content*: StoryPlaces abstracts the location from story content by separating the location from story pages, which has the potential for remapping stories to new locations, but the tool does not provide this functionality. In contrast, Story CreatAR provides authors with the ability to dynamically map content to a new location.

- *Types of stories*: Both StoryPlaces and Story CreatAR provide flexibility in the type of story (nonlinear, branching, etc.), but it is more feasible for authors using StoryPlaces to create longer stories (over an hour). Story CreatAR stories have increased complexity as authors need to maintain a coherent continuous experience and consider complex relationships between the placement of the content and the control the viewer has in the story. Thus, narratives in Story CreatAR have a linearly increasing complexity with story length, making shorter narratives more favorable. This aligns with AR experiences which typically are shorter in comparison to web-based experiences.

Neustaedter and Tang [98] provide several considerations for authors creating locative media content that a locative media tool should support. Their considerations (physical effort, experience duration, accessibility) indicate that certain locations have varying costs to access. Packer et al. [103] similarly associate locations with costs through their locative media guidelines: dealbreakers, pragmatic considerations, and aesthetic considerations. Our evaluation similarly showed that authors are able to think in a spatial way and considered accessibility and distance relations in their story representations and throughout the study. If Story CreatAR was extended and used for a wider range of environments (currently it has been tested in buildings), then we may want to include differing costs for locations depending on the difficulty to reach and access. The cost function could extend the space syntax priorities for a story element in Story CreatAR to include distance and accessibility. A cost function may also be useful for providing higher and lower priorities depending on the semantics of the space (e.g., a bathroom in the physical location may be a lower priority space as it is a sensitive area). The cost function would extend the ability to specify a story element's space syntax priorities (or to specify exclusions) to a story element or floorplan being associated with a *room/region*.

It would be useful to extend space syntax analysis of a floorplan to a 3D model, which is an area of active research [26, 76]. This way we can account for vertical incline in the spatial analysis. This could allow authors to understand where to create optional/bonus locations (e.g., on a steep hill) as suggested by Packer et al. [103]. This could also allow authors to identify vistas in multi-story buildings, degree of spaciousness within areas (indicated by the height of a ceiling), and to identify where two spaces are connected through the y-axis (e.g., hallway on second floor sees foyer on first floor).

From Longford's [84] locative media guidelines, they emphasize the importance of considering a location as a "place" versus just the physical layout. Story CreatAR may provide guidelines for authors to consider (e.g., time of day may impact the story), but the spatial analysis techniques only consider the layout. Our authors made other locative considerations that did not consider the layout such as lighting in a story. Other guidelines for authors may include using "large" rooms to have a higher sense of presence and engagement and minimal decorations to reduce workload [120].

9.2.2 Multi-Site Deployment

The second motivation for this project is providing multi-site deployment. When authors are designing a story for a single location, this requires manually moving all the objects to appropriate locations often via a drag-and-drop interface. This can be difficult when the space is large or the story is long. This becomes even more challenging when an author tries to extend the story to multiple or unknown locations. That is why several tools aim to dynamically deploy an experience to adapt to the location. For example, FLARE [55] and VRoamer [41] dynamically place content based on the immediately visible spatial configuration during an experience. However, these tools do not consider an optimal placement over the *entire* floorplan and do not provide an author facing interface for creating such an experience. Story CreatAR alternatively provides an author facing UI where an author can specify a rule once and deploy it in multiple locations using their rules. This reduces the technical barriers to authors, saves time for multi-site deployment, and allows authors to fine tune the placement more easily than on-the-fly placement techniques (i.e., pre-determined placement can be manually moved in Unity versus on-the-fly techniques would require additional programming to support placement adjustments).

Story CreatAR achieves an optimal placement based on the entire floorplan through spatial analysis techniques. Space syntax allows authors to place objects in appropriate locations. However, space syntax is not used in author facing applications as it is highly technical, no universal set of effective space syntax characteristics for immersive storytelling or game experiences are known, and to date space syntax has only been applied in a limited way to immersive AR experiences. Other spatial analysis techniques used by Story CreatAR can also be applied to other immersive AR experiences to create a site-adaptive experience by relying on spatial theory rather than absolute positions. Proxemics theory relies on the placement of two entities, rather than two absolute positions, F-formation groups can be placed and the F-formation itself defines where objects/characters are placed around the F-formation, and room-based analysis allows authors to specify rooms and their properties dynamically. We broaden the diversity of spatial analysis techniques within the context of immersive AR using proxemics, F-formations, and room-based analysis. We show that authors are capable and are willing to learn spatial analysis techniques, although they encountered some misunderstandings in regards to understanding and effectively using them.

Kán and Kaufmann [80] place furniture dynamically using several interior design rules. Story CreatAR supports some of the interior design rules: openness (space around the object) and room constraints. Story CreatAR has underlying support for the other interior design rules, however, an interface could be added to the placement algorithm to specify distances between objects and how many objects should be instantiated. Story CreatAR could be extended to support placement against a wall using the space syntax characteristic, minimum isovist radial. Additionally, Story CreatAR could integrate the spatial scales defined by Barba [33], which could be used by authors to specify transitions in the narrative. For example, if the author does not want the viewer to touch something, they should not put the object in the figural scale. Figural scales (space occupied by human body) are supported through proxemics and F-formations, panoramic scales are supported by visual complexity and openness, environmental scales are implicitly supported in Story CreatAR's building-scale narrative support, and global scales are supported by providing maps to viewers.

In our evaluation of Story CreatAR we found authors desired to manually place story content and had difficulty thinking of variations of placement on the same or across multiple floorplans. Our evaluation finds suggestions (i.e., programming by demonstration interface) to help overcome the misunderstanding of spatial analysis concepts for nontechnical users. This leaves future work open to implementing and exploring the effectiveness of these suggestions.

Immersive AR Experience

The third motivation for the work is to support a rich, continuous, immersive AR experience. AR has the potential for integrating the physical environment and virtual content in a new and enticing way. We utilize this potential by creating virtual content to be displayed in head-mounted AR. This leaves authors able to creatively augment the physical environment (e.g., adding props and effects) and to display the content in many environments. AR provides a comfortable, walkable immersive experience. However, these benefits come at a cost: viewers can control where they move, where they look, and what actions they perform, but this results in many unknowns for an author of this experience [33, 36, 47, 127]. This means authors have to account for all possible scenarios the viewer may take, which becomes increasingly challenging as the story grows longer and the content becomes more complex. In addition, as a new medium, there are few guidelines and resources specific to immersive AR that authors can use to help them during the authoring process. Since we are using AR, the physical environment has an impact on the experience, which includes both the spatial configuration and the social activities that take place there. We detail in future directions (Section 9.5.2), a visualization that aids in analyzing viewer trajectory and shows where they are looking, which correlates with how space syntax is used in practice [74]. Even if an author knows where a participant is looking, they still need to find how to direct the user's attention to areas of interest. Story CreatAR allows authors to direct user attention through spatialized sounds. Spill used spatialized audio (background audio) to draw users to characters. Spill and Tyson's Peak relied on avatar movements between conversations to direct the user where events are located. In our current work, we developed guidance paths, which we could integrate as a more robust feature in Story CreatAR for directing user attention. The guidance path was created to support Standville Museum. We may also consider using spatial analysis techniques to determine the type of guidance path used (central or sneaky), which is described in detail in Section 9.3.2. Within our evaluation, authors did not experience the stories immersively (i.e., did not control their movements and actions), and there was no other evaluation component on the use of the experiences generated. While, we proposed an idea for how to guide and direct user attention, the effectiveness of this strategy has not been evaluated yet.

Further, for immersive AR experiences authors are faced with significant impediments. Authors may be able to create a lower quality experience with minimal programming knowledge, but to create a high-fidelity experience authors or someone in the team often require advanced programming knowledge [13, 78]. Story CreatAR provides a user interface for authors to use rich story elements (e.g., realistic avatars) and the option for authors to add their own content (with no programming required), however the scope of the stories the authors can create is currently limited to avatar-driven narratives. In addition, authors often are subject to misconceptions about AR [78]. When we created Story CreatAR we discussed with our authors some aspects of immersive AR, including interaction modalities, features offered (e.g., untethered headset), and differences to VR (virtual content is augmented on the physical environment).

9.3 Story CreatAR Extensions

9.3.1 Spatial-Narrative Mappings

From the mappings we brainstormed in the design for Story CreatAR, we may want to consider also including the following to provide guidelines suggested in the literature and support possible mappings our authors desired in their story representation.

- Distance walked could refer to time passing in the narrative. This mapping can be used to adjust the story to the physical abilities of the audience (e.g., walking fast means time in the story passes quicker) as suggested by Neustaedter and Tang [98]. In Story CreatAR, we could keep track of the distance walked by a user by using the position of the headset. This could be used to decrease/increase the duration of timed events.

- Our authors specified that the viewer would have narrative choices in the story, but did not always specify how a viewer would choose one from many choices (e.g., voice command). One way to provide viewers with choices is to use doors in a room or hallway to represent a choice and to use room-based connectivity values to determine the maximum number of choices a viewer has. Thus, viewers can follow the path they physically choose (e.g., run into a *burning* room to save a baby from a fire or go through door two to go seek help). To achieve this we need to expose doors as a variable to authors such that if a viewer walks in one door, the variable is set. Connectivity can easily be integrated as the values are already generated by the space syntax analysis we perform with depthMapX. We have access to door locations through AFPlan. We need to provide access for authors to set and modify variables and to create conditional events.

- Multiple authors described placement in terms of accessibility and traffic (not currently exposed to authors in Story CreatAR), and Eric specifically has sections of the story where he creates tension (e.g., Shadow character chasing viewer). Story tension could be created through bottlenecks in the physical space. For example, we may be able to determine bottlenecks through the space syntax characteristic, *gate count*, which measures how many agents have walked through a door.

- Foreshadowing in Standville Museum is created through security monitors that show a Shadow character walking towards the viewer, however the cameras for the monitors are placed manually. We may consider foreshadowing and flashbacks to be mapped to vantage points in the story. For example, in Standville Museum an author may be able to dynamically use vantage points for the position of the cameras rather than manual placement.

From the mock story ("The Three Little Pigs") one additional mapping was derived that was not implemented in Story CreatAR: voice commands can be a precondition for an event. In our current work, authors incorporated voice commands as they are easy for viewers to learn and use. We can expose voice commands as a precondition to authors by using MRTK's voice recognition system.

9.3.2 Integrating Natural Movement Patterns

A research colleague has worked on using space syntax rules generated by depthMapX to emulate natural movement behaviors for characters in a story. Currently, Story CreatAR avatars use A* path finding for movement, which simply finds the shortest path rather than a natural path. The research colleague describes two ways to describe character movements using space syntax: *sneaky* and *central*. They consider a *sneaky* path to be one that has good vantage points and is on the outer edge of a space. They consider a *central* path to be the opposite, with high visibility.

The research colleague modified the A* path finding algorithm to account for weights determined by space syntax. They used the space syntax characteristics *isovist min radial* (distance to a non-navigable surface such as walls) and *isovist drift magnitude* (distance between the current point and the isovist's center). High drift magnitude and low min isovist radial indicates a sneaky path and the opposite indicates a central path. We can integrate this into Story CreatAR by adding another property for the traversal event: type of path (sneaky or central).

9.4 Current Work

Figure 9.1: Dog talking to active user in Standville Museum, shown in AR.

This section details current work, but is beyond the scope of the thesis. This work builds on the VR experiences from our evaluation of Story CreatAR, discusses insights gained from translating the stories from VR to AR, how the authors stories influenced the creation of a new map, and how authors manually placed their story content compared to how Story CreatAR places story content using space syntax. This work is part of a study that took place during the *Nocturne Art Festival* [4] in Halifax Oct.13th – 16th, 2021. The REB approval letter and consent form can be found in Appendix F. We demoed two immersive AR stories: Standville Museum and Spill. A snippet of Standville Museum is shown in Figure 9.1. I worked closely with the author Eric and his supervisor Amy to implement Standville Museum and thus many insights will be from my experience iteratively implementing and testing Standville Museum.

During Nocturne we demonstrated two stories, Spill and Standville Museum, in an approximately six-minute long two-player immersive AR experience. Therefore, we have eight conditions for our study: one location (Museum of Natural History) x two stories (Spill and Standville Museum) x two placement conditions (author specified and space syntax) x two sharing factors (observer and guidebook).

The stories were originally created as part of the developer using Story CreatAR phase in our evaluation and deployed to VR. Therefore, objects were placed based on the spatial analysis placement generated by Story CreatAR. The first step to prepare for Nocturne was to deploy the story to AR using the HoloLens 2. When translating the story from VR to AR we gained several insights on the process.

- From a technical perspective, the *different deployment target* meant working under a different platform in Unity (switching from Android to Universal Windows Platform). For VR interactions, we used the Oculus Integration package (supported by MRTK) as it was more streamlined with the Oculus Quest, which allowed for rapid prototyping. However, for AR interactions we used MRTK. This resulted in new ways of interacting with the content: instead of controller-based interactions we were able to perform gestures, use gaze, and voice commands. We recommend authors prototype in VR as it has a shorter build process and increased debugging support, and then deploy to AR to test the experience in the target space.

- *Device performance* is the quality of the experience that the headset is capable of rendering. Different AR/VR headsets can achieve differing performance levels. We found when transitioning from the Oculus Quest to the HoloLens 2, we encountered a decrease in performance for the same experience. For example, a fairly detailed telescope in Standville Museum had to be removed from the AR scene to increase performance. We recommend considering the different device's capabilities and how the certain story aspects effect them (e.g., number of triangles on a 3D object).

- *Spatial mapping* is not an issue in VR as it does not require aligning the virtual and phsyical worlds. There are several methods for aligning (both position and orientation of) AR content: image tracking, selecting two known points, and placing an anchor on a surface. We used image tracking with a QR code because it is useful for multiplayer experiences as it provides the same calibration over multiple experiences. More information on spatial mapping can be found at [81]. Authors need to account for the calibration process when deploying the stories in AR.

- A new challenge imposed by varying floorplans is the *physical size constraints*. An issue we encountered with our study was that the designed virtual floorplan was much larger than the target physical floorplan in AR, which resulted in some issues with the placement of the content. For example, a medium sized room in the virtual floorplan was much larger than the medium sized room in the physical floorplan as the size is relative to the size of the overall space. This room was intended to include large furniture such as a couch. However, due to the size limitations of the physical floorplan, this object was excluded from the experience.

- A related challenge is that of *experience testing*. In VR, the experience can be tested virtually anywhere as long as it meets minimal size constraints (e.g., about the size of a small office). AR can be tested using a remote space, but there are two notable issues. First, if the content is placed following the sample floorplan, the experience would be fully usable in this space, however, the expected experience may not reflect the experience in the target floorplan due to differing spatial configurations. Second, if a user imposes the target floorplan to control the spatial configurations, there may be issues caused by misalignment (e.g., limiting the the maneuverability around the space and potentially having inaccessible content). Therefore, the optimal AR experience requries on-site testing, which can take more time and effort to do. In our case, we were only able to perform on-site testing the week before the study was meant to happen.

- *Tracking* can be lost in walkable AR experiences, which breaks immersion and can cause disconnects. However, this is less of an issue in VR due to most experiences being at room-scale or stationary.

- The *context of a location* is an interesting aspect of AR experiences. We deployed to the Museum of Natural History, which had a similar atmosphere to one of the stories we deployed, Standville Museum. However, the space we had available within the museum was an isolated large empty room, which lacked the context of the museum. Due to the lack of additional rooms, we created our own floorplan using room dividers. While, this is not how Story CreatAR was intended to be used, future work could explore how to design a floorplan to satisfy spatial characteristics of a story. In addition, we also had control over the physical props used in the space, which could be placed using the spatial techniques provided by Story CreatAR.

We also added new features to the stories to prepare them for Nocturne. This included adding a new floorplan and making content adjustments/additions. At the Museum of Natural History we had access to a room that is approximately 30 × 30 feet. To fit the constraints of our stories (and to make the spatial configuration more interesting) we needed to divide this space into rooms. Based on Spill, the only constraint was having at least two rooms and one room has one door. The rest was designed very flexibly. Based on Standville Museum, there were several more spatial constraints, one identified from the script: having at least six rooms as they were all used in the story, and some from the development process: two rooms need to be connected such that through the door of one a user could see a “demon” circle in the other room, some rooms had to be large enough to fit all the furniture (challenge due to small location), and one room required a long wall with no obstructions as it had a mural on it. Story CreatAR should be more conscious of the size requirements based on content size, which can be achieved by comparing the size of objects compared to the size of the room.

Additionally, we had to iterate on the development of the story and the content in the story to meet the time constraints of the experience. Meeting the desired time constraints was challenging as it relied on testing the experience on the desired floorplan, as a larger floorplan would take more time to experience (e.g., larger distances to walk). For Standville Museum, there are two paths in the story that is determined based on player interaction (speaking "yes" or "no"). Both paths had to provide similar content and be close in length. Story CreatAR could estimate experience time based on how long it takes a user to walk through story elements and how long it is expected to take the user to interact with events (e.g., listen to a conversation for the duration of the audio lines). Authors were iteratively shown versions of the story as it progressed using a sample floorplan (fourth floor of the Mona Campbell building). When we switched to a new floorplan, we had the authors choose the placement themselves to investigate how authors consider placement in the target location, without explicitly considering spatial analysis. Considerations they had could drive future spatial analysis support of Story CreatAR. We met with the authors at the Museum of Natural History, where they first set up the physical props they would like to use in their story. Then, we sat side-by-side and my computer showed the story elements in Unity. They instructed me where and how the story elements should be positioned and oriented. However, one interesting suggestion from both authors was to modify the floorplan: both wanted to obstruct a doorway (e.g., placing a cloth over a door to make it not accessible) to better suit their story. By placing story content while in the physical environment, authors were better able to consider how physical props and objects affect the story. This was not seen in our evaluation, as within Story CreatAR and with a VR recording (lack of immersive first-person perspective of the experience), the authors think more of virtual elements. However, if authors have more dynamic props (e.g., blanket), they are able to get more creative with different design decisions.

Both authors manually placed the content of their story for Nocturne. Ryan matches the spatial rules from his graph representation as he "designate[d] room furthest from front door to be Fokthipur's Room", had the largest, most connected room as the hallway, and had decorations placed away from each other. Eric makes more adjustments to his story spatial specifications, perhaps due to the more precise descriptions he provided. Eric specified in his script the bathroom camera would be close to the door, but the camera was as far from the door as possible. Eric wanted the camera to be placed close to a riddle that appears on a wall, but due to the size of the walls, the riddle had to be placed across from the door. In Eric's story script the security room was specified to be far from the bathroom, but when Eric placed the security room in the museum space, he placed it beside the bathroom. The placement of the rooms changed as Eric was also considering the physical entrance and exit of the space. In floorplans created for Story CreatAR it may be useful to specify the entrances and exits of the overall space to consider the flow for starting and ending the experience. Eric did describe and chose the security room to have one door. Similarly in both Eric's script and manual placement, the dog's room was small and the dog was sitting in a corner.

9.5 Future Directions

9.5.1 Comparing AR Narrative Placement Methods

Currently, we have only informal, subjective impressions that the placement of story elements, event composition, and interactivity supported by Story CreatAR were effective for those experiencing the story. We propose a comparative study to investigate the utility of spatial analysis techniques used in Story CreatAR. The proposed study compares two locations: one which will have a high correspondence with the flow patterns predicted by space syntax (e.g., space syntax predictions of the number of people that pass through a door closely matches what occurs in the real world) and one which will have a low correspondence. The study also compares placement methods: spatial analysis from Story CreatAR, random, and manual. The approval letter of the REB and consent forms for this study can be found in Appendix G.

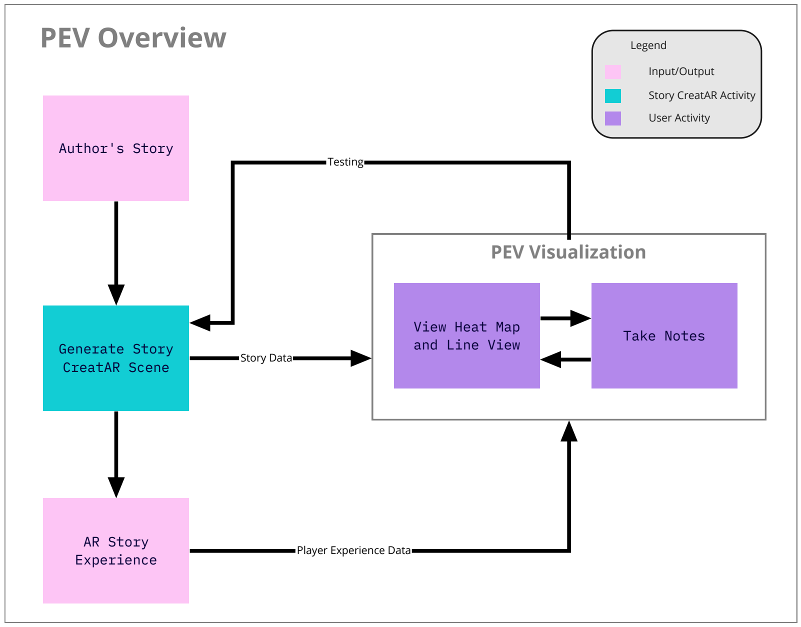


Figure 9.2: PEV Overview

9.5.2 The Story CreatAR Player Experience Visualization (PEV)

Figure 9.2 provides an overview of PEV: a player experience visualization I created specifically for experiences generated by Story CreatAR in my visualization class (CSCI 6406). This visualization is for analyzing the interactions from users experiencing the story created through Story CreatAR. To demonstrate the usefulness of the visualization, I deployed a story created in Story CreatAR to the Oculus Quest and recorded interaction data. PEV utilizes the story data generated from Story CreatAR and the player experience data from the target device to create visualizations. The author can analyze the heat map and line view visualizations, and add notes of their observations. A similar visualization has been used to determine user experiences [115], however, this visualization is suited for experiences in Story CreatAR. Specifically, it may help inform authors if the viewer deviates from their expectations (e.g., skipping an important event), and then they can choose to adjust their story in Story CreatAR. This process is repeated until the author is satisfied with how players experience the story. PEV is implemented, but not integrated with Story CreatAR. As this tool is designed to be used for reflection, it may be useful for analyzing player experiences in our comparative study.

Gathering Data

To show the utility of the visualization, a simple sample story was created using Story CreatAR and then deployed to VR. Using Story CreatAR a Unity scene was populated with a fireplace and a conversation between two avatars. The generated scene was exported into a new Unity Project for the visualization of the player experience. The story data JSON file generated by Story CreatAR was copied to the Resources folder of the visualization project. This JSON file is used to access which story elements are involved in the story, what type of story element they are (one of Avatars, Objects, Sounds), and where they are located.

The next step was deploying to VR. The OVRPlayer (which represents the VR player) and teleportation controls were added using Oculus Integration [8]. Teleportation controls were used to reduce the effects of locomotion (e.g., nausea or dizziness), which commonly occurs if a player moves in VR using joysticks. Additionally, a virtual menu was added to have precise control of when to start and stop the recording of the player experience information. The player experience recording saves an object with a list of three-dimensional position and rotation data of the VR player, as well as the timestamp for each time the position and rotation data were saved (occurs every Unity frame). The data is saved locally on the Oculus Quest, which can be accessed through SideQuest [2] and moved to the Resources folder of the visualization project. Using the sample story, three player experiences were created.

Authoring Support

Looking at Figure 9.3, there are two main sections to the visualization: the map view on the left (darker blue) and the data view on the right (light blue). In the left section the top bar shows the dropdown menu of which visualization view to choose (path view or heat map) and the title of the story (e.g., "Sample Story"). The center area shows a top-down view of a map. On the bottom-left of the map there is a legend describing types of story elements available in the interface: avatars represented by a red person icon; objects represented by a blue cube icon; sounds represented by a yellow audio icon.

The Stories.json file is used to determine the name of the story element, the type of story element, and its location. Then, the story element is placed as an icon overlaid

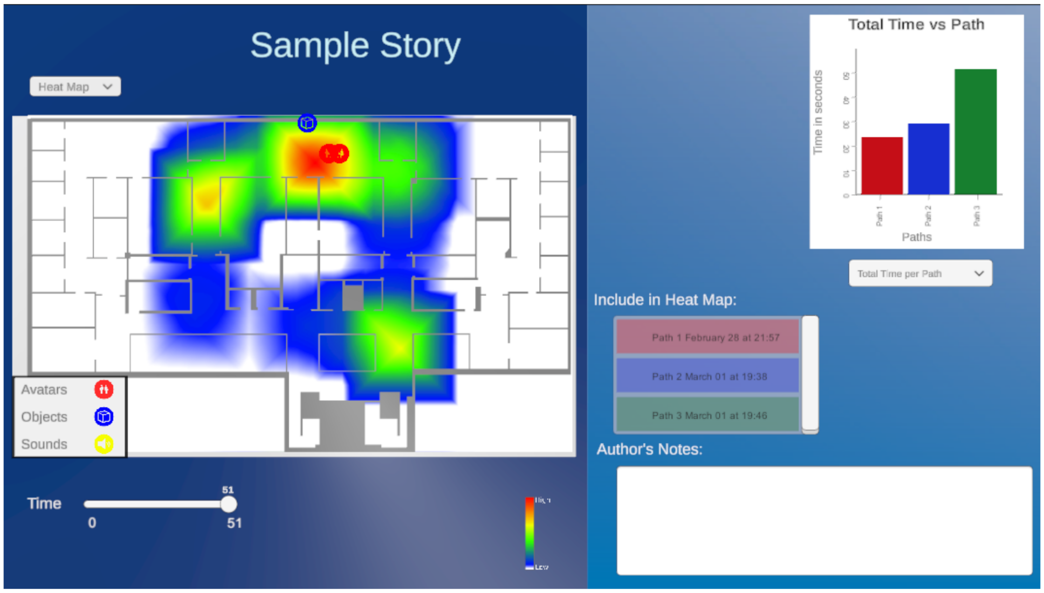


Figure 9.3: Visualization Layout

on the map in the proper location. The story element icons are interactable in two ways. First, if a user hovers over a story element icon, it enlarges, and the name of the story element will appear. Second, if a user clicks on a story element that is part of a conversation, the conversation dialogue will appear. For example, clicking on an avatar will show dialogue for the conversation they are in. In the case for this story as the avatar's dialogue is audible and not provided in a text format, sample dialogue is shown for the characters.

Two aggregate bar graphs are used to provide the author with another way to view the information. One graph compares the total time between each path and the other compares the amount of each type of story element is in the story. Additionally, the author has a text input box where they can save notes on the experiences. For example, they could note that the player experienced the story at nighttime, where the darkness outside added to the suspense in the story.

Path View

A Unity line renderer was used to represent the player paths using the tracked position data. The alpha value of the paths is 90% to prevent occlusion and each full path can be either one of 12 distinct colors or have the color encoded by time. For example, the red color represents time zero and the violet color represents the end time (longest time of all paths). The paths are encoded with a percentage of this rainbow gradient. By default, the time slider is at the end time and the lines show the entire path. The author can adjust the time slider to only view the path up to a certain time. On the top of the time slider handle there is text that represents the current time in seconds.

On the right-side of the visualization, there is a filter section for the paths. The paths are named as “Path X Month Day at HH:MM” (e.g., Path 1 February 28 at 21:57) to give the author a sense of when the experience occurred. The filter section permits each path to be toggled on (visible) or off (invisible). The author can also click the button for the path, which highlights the path on the map and provides a description of the path. The description shows the current position and rotation of the player (dependent on the current time displayed on the time slider). It also shows the total time of the path in seconds.

The author may select the toggle to see the FoV for the player at any point in time. This is important as the FoV for the Oculus Quest is 90° as opposed to the FoV for a human which is up to 220°.

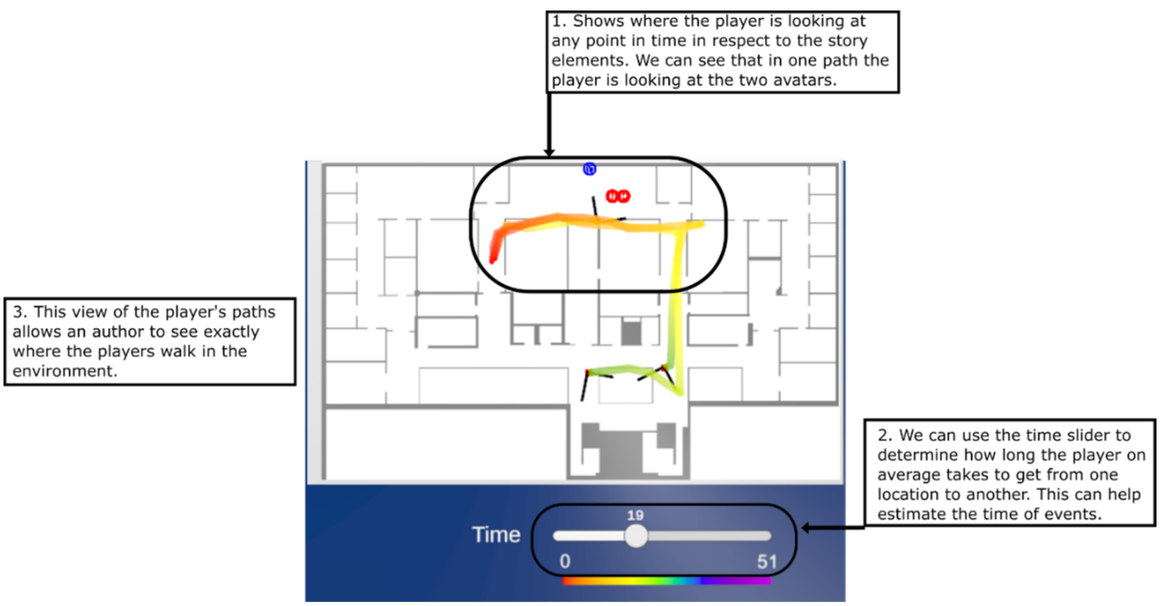


Figure 9.4: Path view annotated

Figure 9.4 shows the player paths overlaid on the map (path view). The following list describes the annotations shown in the figure.

1. Shows where the player was looking at that moment in time with respect to the

story elements. This can inform whether a story element should be moved to be in a more visible or a more hidden area.

2. Shows that the time slider can be used to view where the player was at different moments in time. Therefore, the author can know without experiencing the environment themselves, approximately how long it takes to get from one point of interest to another. This can be useful for determining when to sequence events.

3. This visualization shows exactly where player's walk in the environment. Knowing where players walk is important for placing objects in appropriate locations and knowing where events should occur.

Heat Map

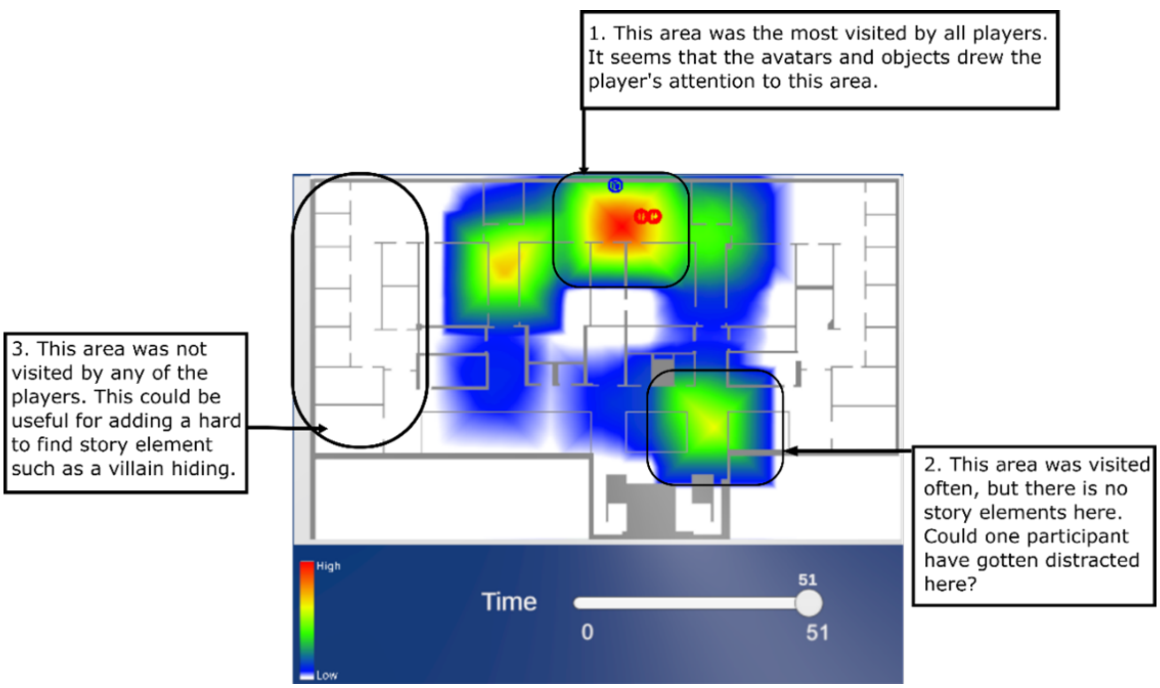


Figure 9.5: Heat map annotated

The heat map shows where the player has travelled the most. I created a heat map in Unity by first creating an image overlaid on top of the floor in the 3D map. Next, I created a gradient material for the heatmap, where red represents the most player activity (high) and white represents the least (low). To determine the color of the gradient for each pixel I performed the following steps.

1. Initialize a heat array the size of the map (470 x 290) to 0's.

2. Go through each position the player was at and add weight to itself and its r nearest neighbors in the heat array, where r can be changed in Unity.

3. Find the maximum value of the heat array.

4. Since the index of the color at each point in the gradient can be represented from a number between 0 and 1, I chose that index to be the pixel's value for the heat array divided by the maximum value.

5. I set this color to be the texture of that pixel.

When all these steps are done, I apply the texture to the image that is overlaid on top of the floor in the 3D map. Like the path view, the time slider allows the author to view the heat map using position data up until a certain time and there is a legend showing the high and low values of the heat map.

Figure 9.5 shows how players experienced the heat map using all three player experiences. The following list describes the annotations in the figure.

1. Shows the most visited area on the map. Unsurprisingly, this area contains the story elements for this story. The story elements could explain why players focused their attention there.

2. Shows an area that was visited a moderate amount. This begs the question of why a participant spent more time there than its surrounding areas. Was it due to one participant getting distracted by something? Therefore, being able to take notes in PEV is important for remembering such external factors.

3. Shows an area that was not visited by players. As Story CreatAR is a tool focused on placement, this is valuable for understanding where a good hiding spot could be for a story element.

9.5.3 Deficiencies to Address

The following lists deficiencies with Story CreatAR and how to address them.

- To support an *iterative workflow* requires authors to frequently add, modify, and delete story components. I suggest to make all of Story CreatAR functionality editable.

- Despite the discussion of spatial analysis concepts during the conception of their stories, authors require additional support for *spatial analysis comprehension* than provided by Story CreatAR. As suggested by the authors, Story CreatAR would benefit by integrating simple definitions, examples, and use-cases of spatial analysis concepts. In addition, authors would benefit from having multiple floorplans shown simultaneously to emphasize flexible placement.

- Although the high-level attributes were intended to overcome the complexities of the lower-level spatial analysis concepts, authors also misinterpreted these attributes. The solution would be a more appropriate set of high-level attributes that would be meaningful and useful to authors. To find this set of attributes, I suggest examining a large sample of authors creating new attributes and then finding the commonalities. Alternatively, a closer inspection of the attributes may suffice: renaming the attributes or providing an option to view more context in terms of how the attribute is derived, how it should be used, and a more detailed meaning.

- When creating a traversal event, authors were confused that they could only have an avatar traverse to a conversation node. Story CreatAR could benefit from allowing avatars to traverse to a room (i.e., randomly placed within), an object, or another character.

- After modifying the placement in the Unity Scene and returning to Story CreatAR, the modifications would be lost. Story CreatAR may maintain the authors modifications by asking the author to specify which placement rules are appropriate for their manual modification based on the spatial characteristics at that position.

- The evaluation of Story CreatAR involved three authors that participated in the design of Story CreatAR (i.e., their stories motivating features). Additionally, we discussed spatial analysis concepts and our research questions. Future work may investigate how authors unaware of our research questions on the use and understanding of spatial analysis concepts would use the tool. This may produce a different set of spatial analysis concepts desired by the authors. However, this could require additional features to be implemented in Story CreatAR to support their stories.

9.6 Summary

I presented the main motivations for Story CreatAR: allowing authors to adapt experiences to multiple sites and providing a rich immersive AR experience. Current work involves a study that was conducted during the Nocturne Art Festival. We compared sharing factors (observer or aware guide book) using two immersive AR stories: Spill and Standville Museum. In future directions, I discuss a potential study for comparing the placement technique used (spatial analysis, random, manual) at two different locations (one with high correspondence to spatial analysis techniques and one with low). Additionally, future work may investigate the utility of a player experience visualization designed for Story CreatAR to show discontinuities in a player's experience.

Chapter 10

Conclusion

In this thesis, we address several challenges with creating an author tool for walkable locative AR narratives. One challenge with designing locative AR narratives is designing for changing or unknown locations, especially when there is a lot of content. We created Story CreatAR to address this issue, as it automatically maps the story content to different locations based on spatial rules that were defined once by an author. The implementation of Story CreatAR followed user-centered design, which involved authors' stories motivating the features offered by Story CreatAR. An important issue with creating locative media content is mapping the story content to the spatial configuration and understanding the effectiveness of these mappings. Story CreatAR aims to addresses this issue by abstracting the spatial features with higher-level spatial rules, which can be associated with narrative elements. We investigate the effectiveness of these mappings by examining how authors used and authors understood them in a study with different phases. These phases include: authors creating their graph representation of their story, authors using the Story CreatAR interface directly, and developers using Story CreatAR. We found authors misunderstood spatial analysis concepts and to help authors we suggest to provide a programming by demonstration interface. We also found authors have difficulty thinking of site-adaptive placement and to help authors we suggest providing variations of the placement across the same or different floorplans simultaneously. Lastly, we find authors desire a wider range of spatial analysis characteristics to achieve their desired placement, which should be incorporated in future work. The tool Story CreatAR and the insights regarding mapping narrative elements to spatial qualities can be applied more broadly to locative AR experiences such as interior design, AR games, and exhibits.

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Appendix A

Sample Interview Questions

These questions were asked during Phase One: User Interviews.

- Please tell me about yourself (education and background).
- Could you describe a couple of your previous media/writing experiences? If any of these are specifically location based, describe those.
- Could you describe the most important tasks or goals for you when creating work related to your field (storytelling/media)?
- Could you describe your expectations for creating locative media through a digital interface that will be shown in AR? What do you expect to be there? What do you need to do? Do you have a specific flow in mind? If yes, please explain.
- How much control do you see the user experiencing the story having? Should they be completely guided by the story?
- What is your target audience? How do we get and keep them engaged?
- Do you have a message to get across through your arts?
- How do you envision someone experiencing your work? Is it discrete locations or is it continuous?
- How can your work be incorporated in a space (examples)? Can you show us an idea how it can be implemented to a place you are familiar with?

Appendix B

Story CreatAR User Interface

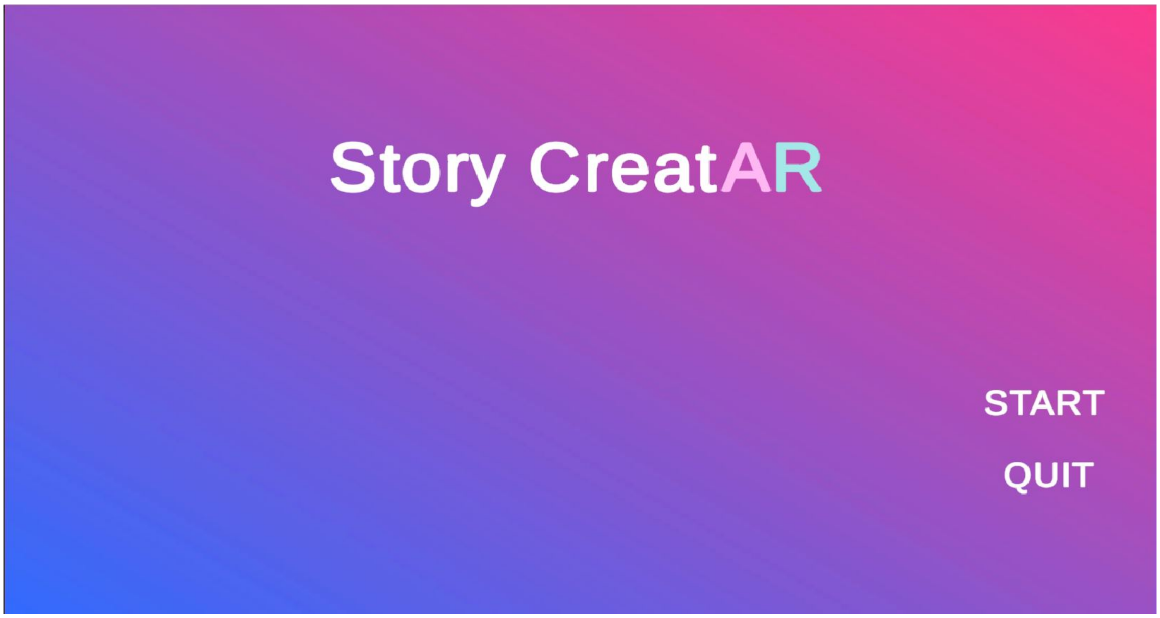

Figure B.1: Start Page

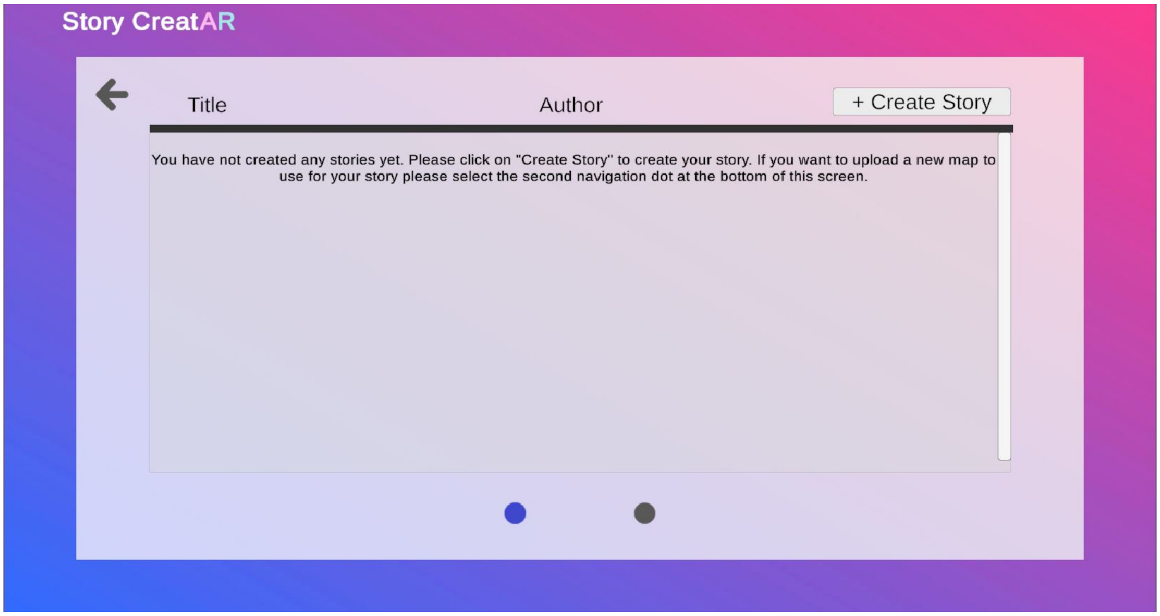

Figure B.2: View stories screen: no stories added.

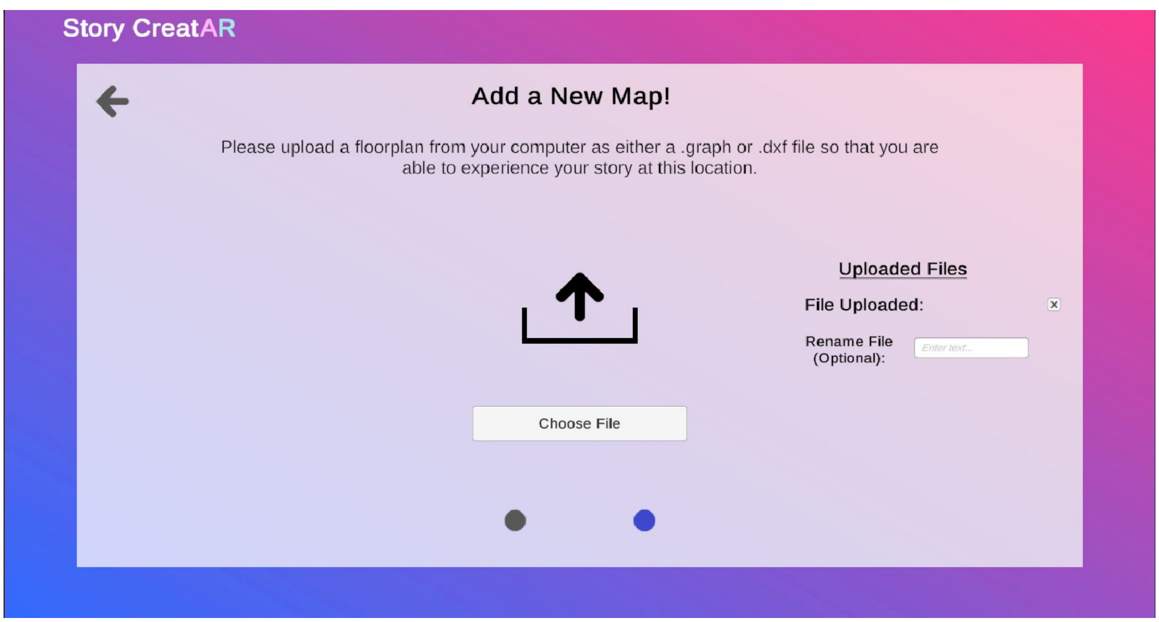

Figure B.3: Upload a new map

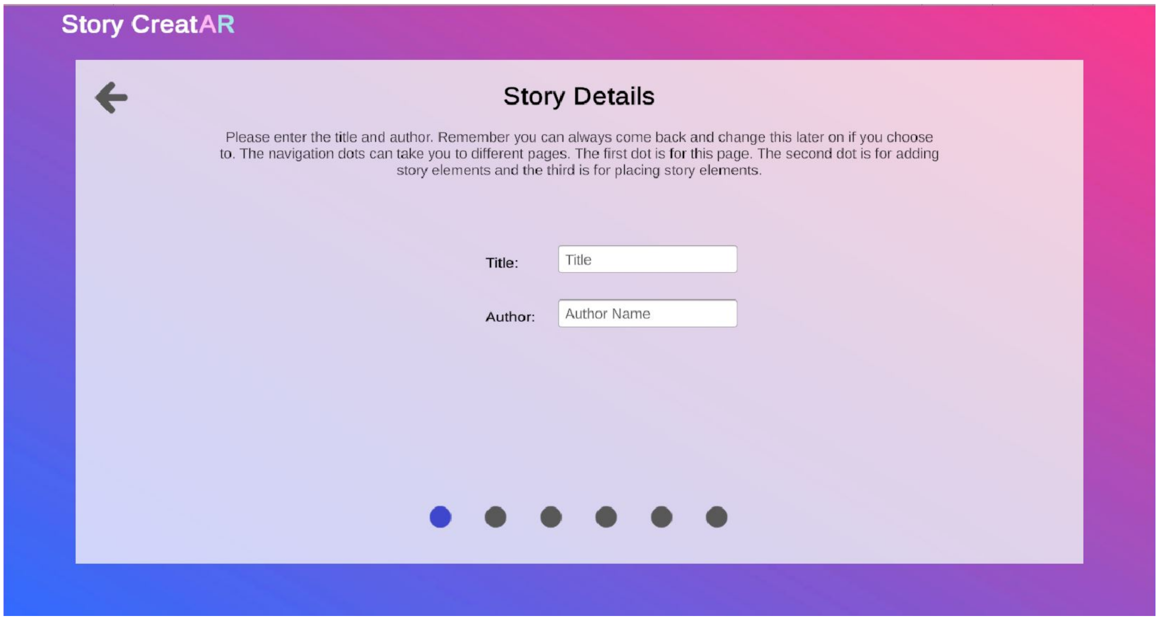

Figure B.4: Story Details — title and author

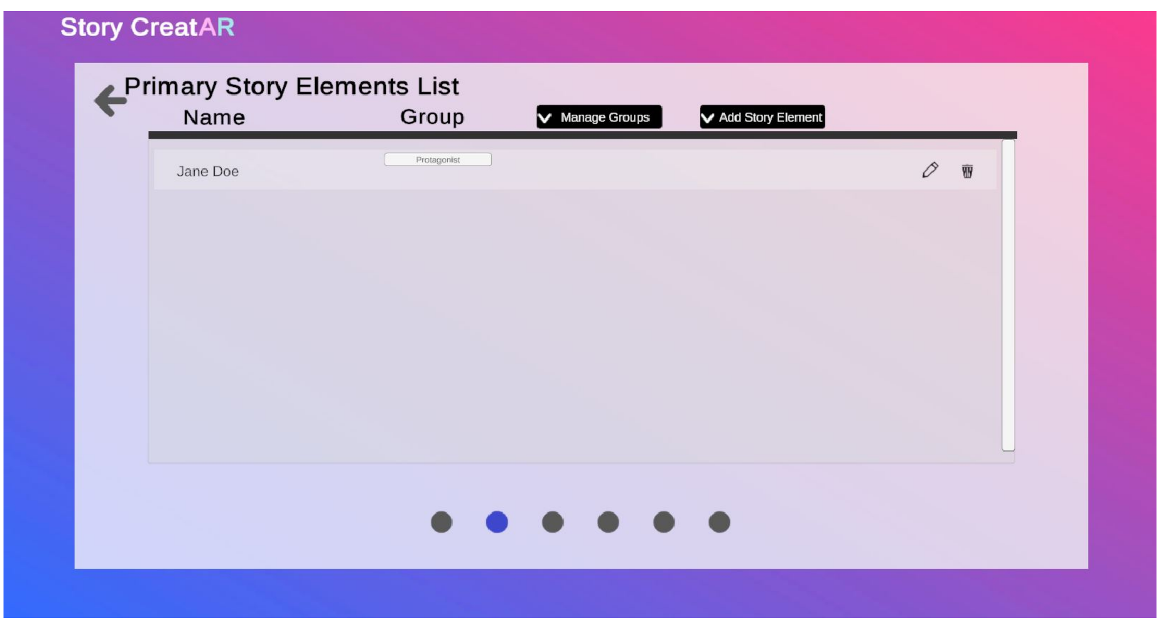

Figure B.5: View story elements screen

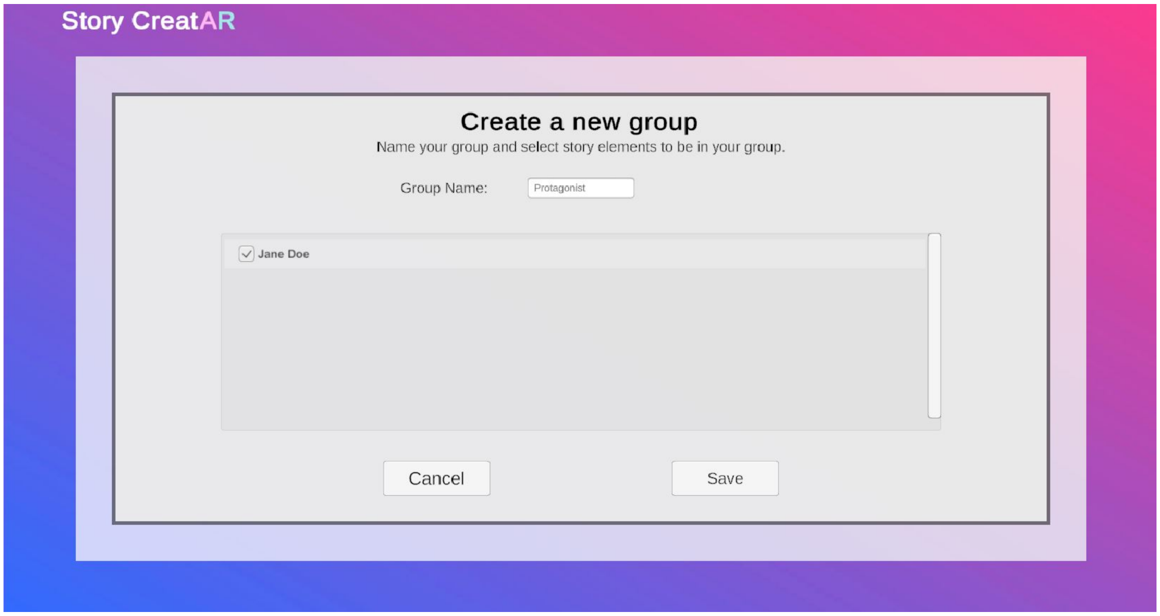

Figure B.6: Create a new group

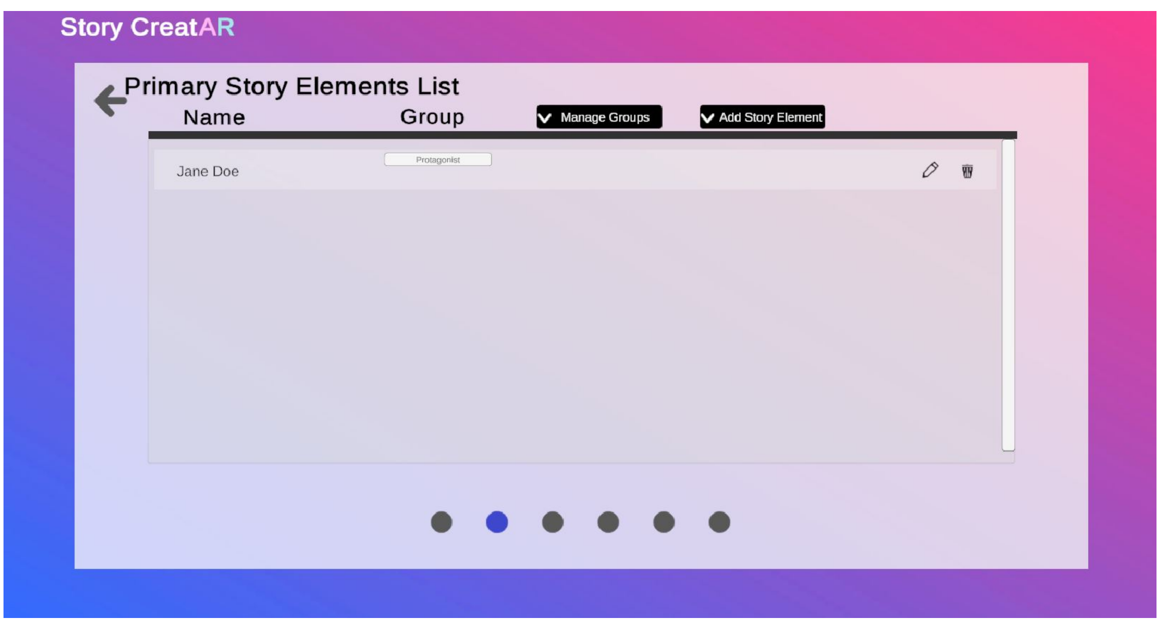

Figure B.7: An avatar story element added and assigned to a group.

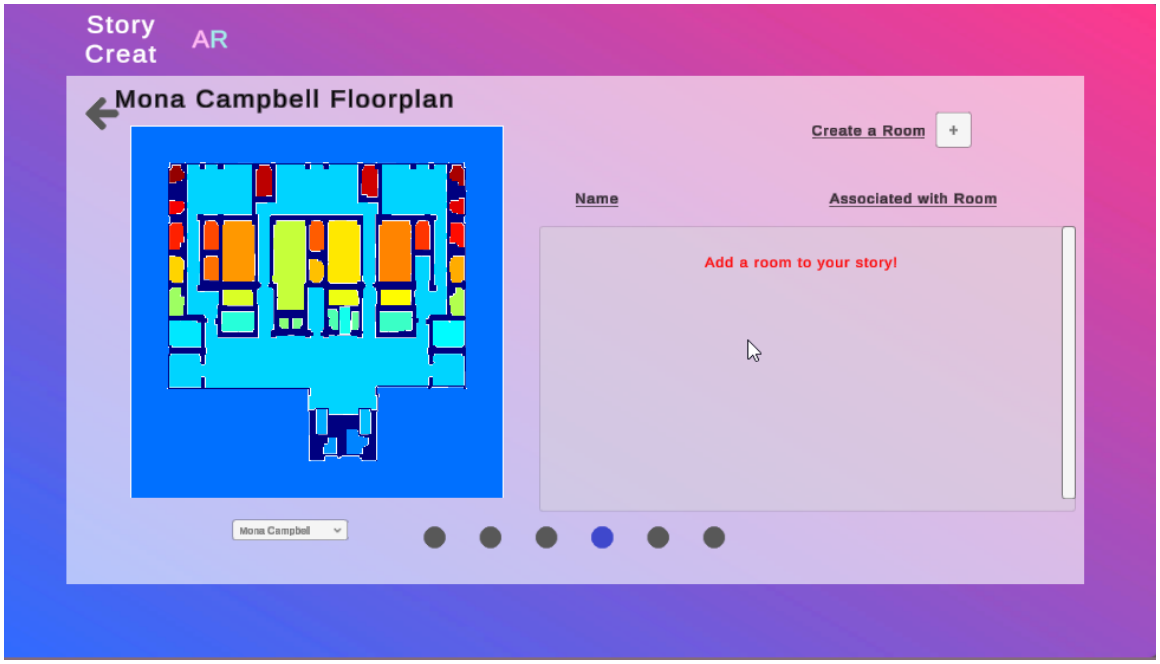

Figure B.8: Create a room screen, no rooms added.

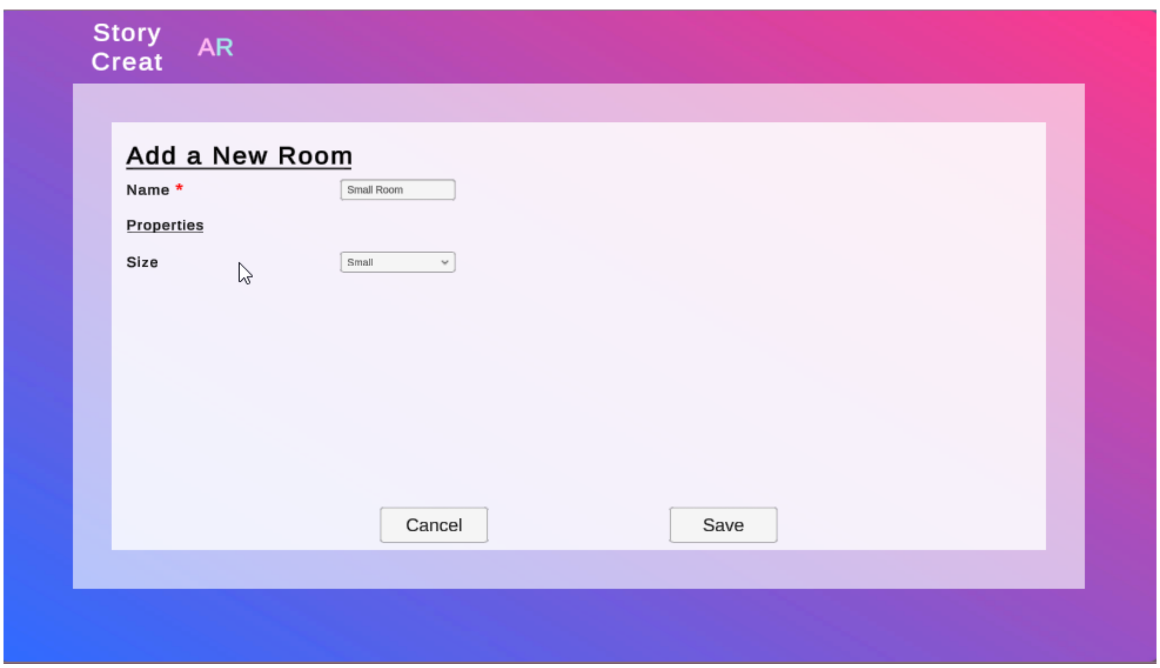

Figure B.9: Adding a new room by specifying its name and categorical size (small/medium/large).

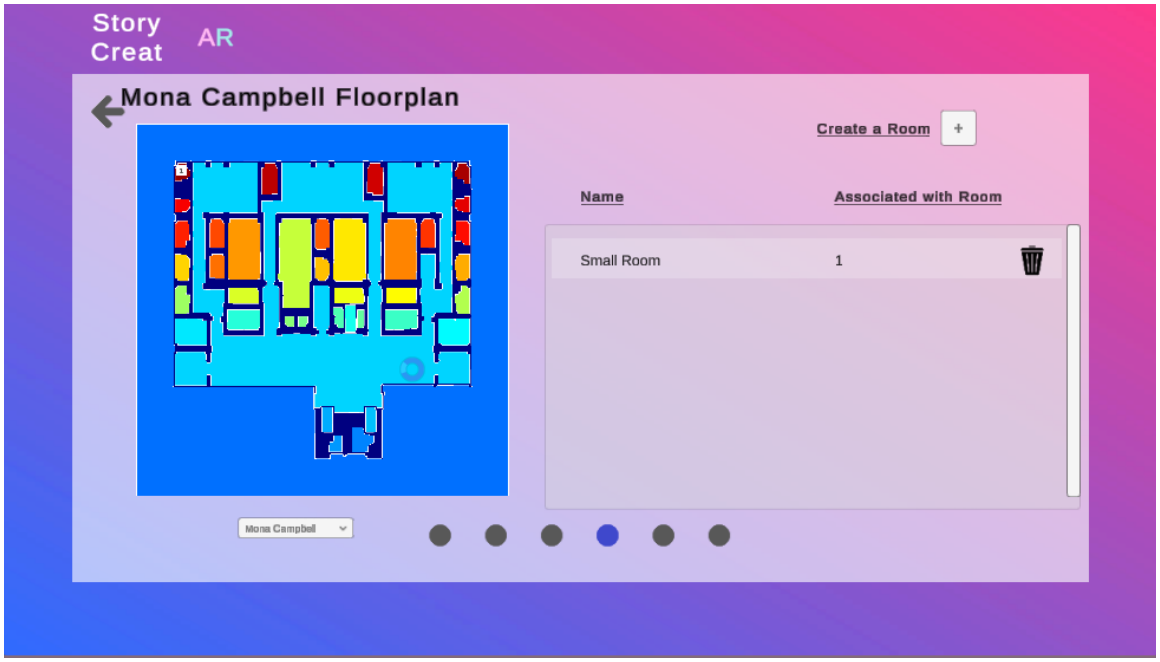

Figure B.10: Create a room screen, one room added and shown on Mona Campbell floorplan.

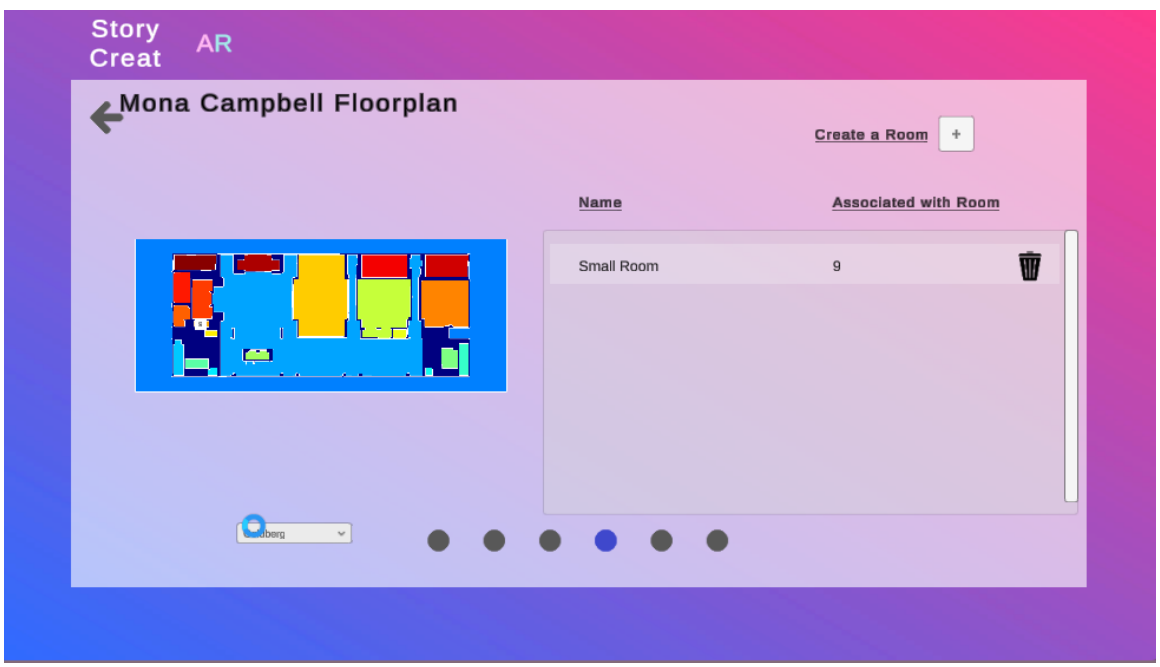

Figure B.11: Create a room screen, one room added and shown on Goldberg floorplan.

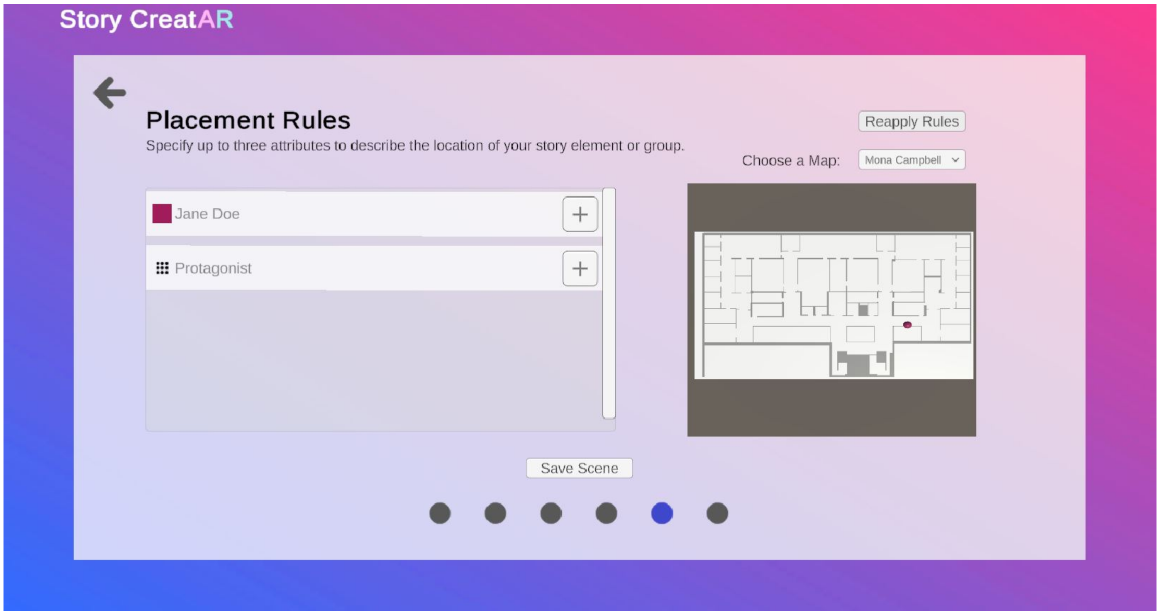

Figure B.12: One version for the placement on an avatar

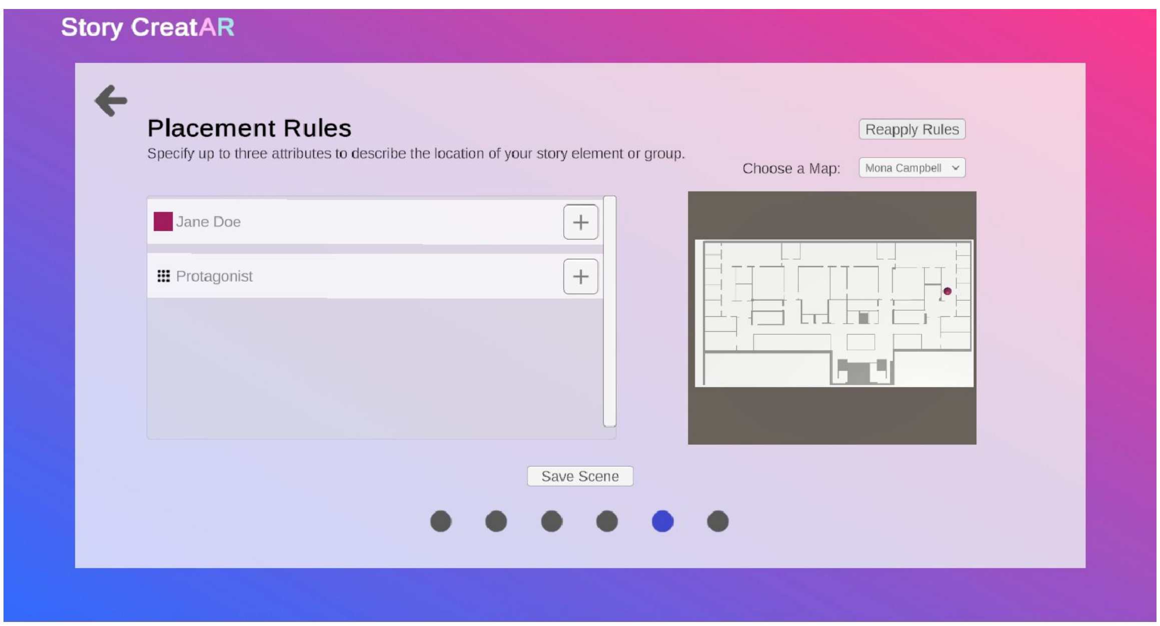

Figure B.13: Another possible placement generated by reapplying rules.

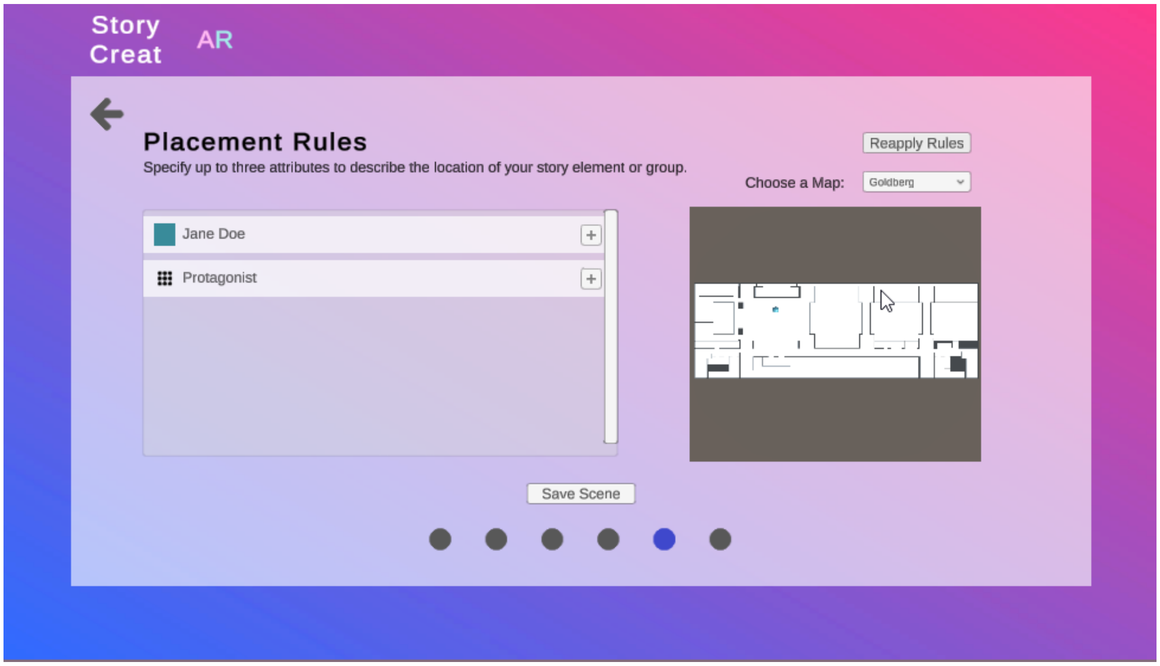

Figure B.14: Another possible placement shown on a new map.

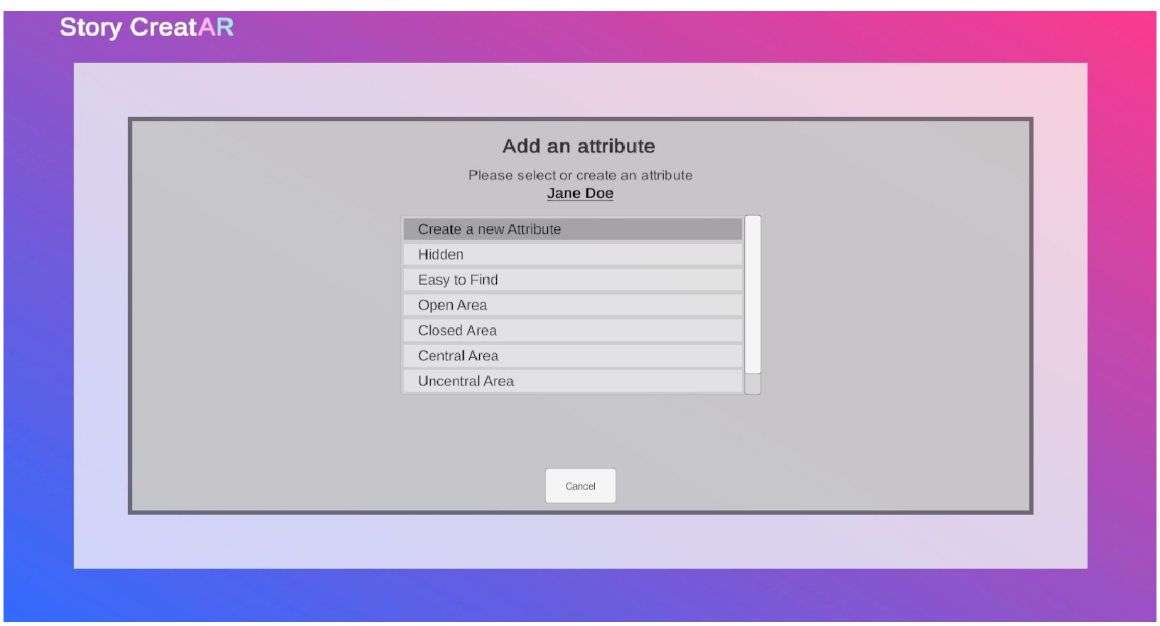

Figure B.15: Authors choose default attribute or create their own.

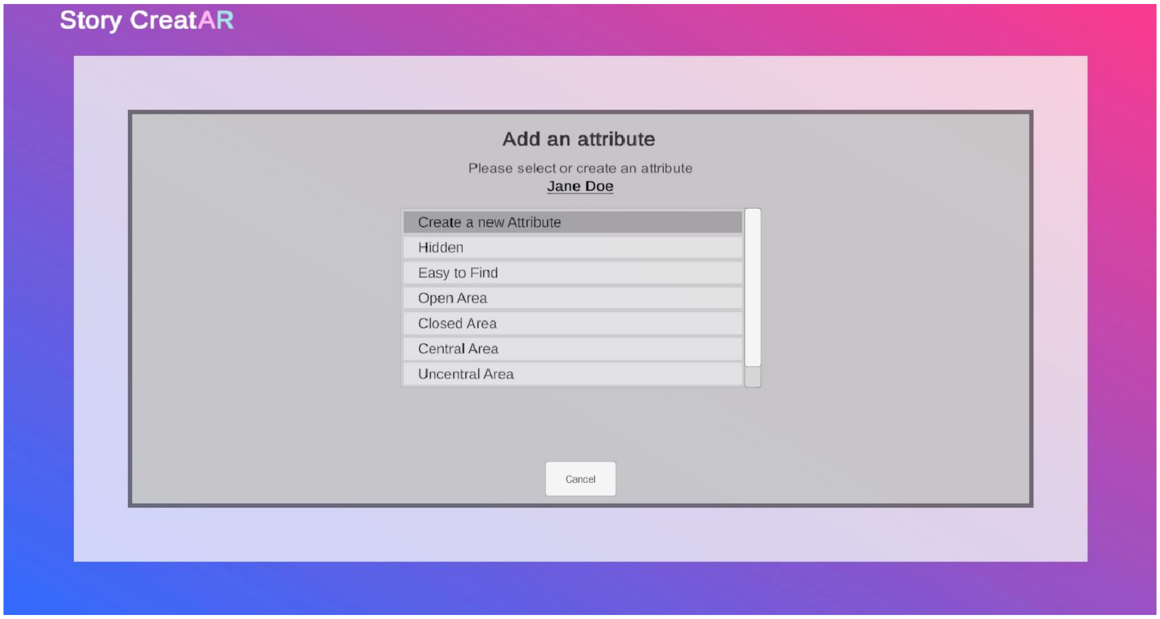

Figure B.16: Authors can create their own attribute by specifying high/low values for visual complexity, visual integration, and openness and giving it a unique name.

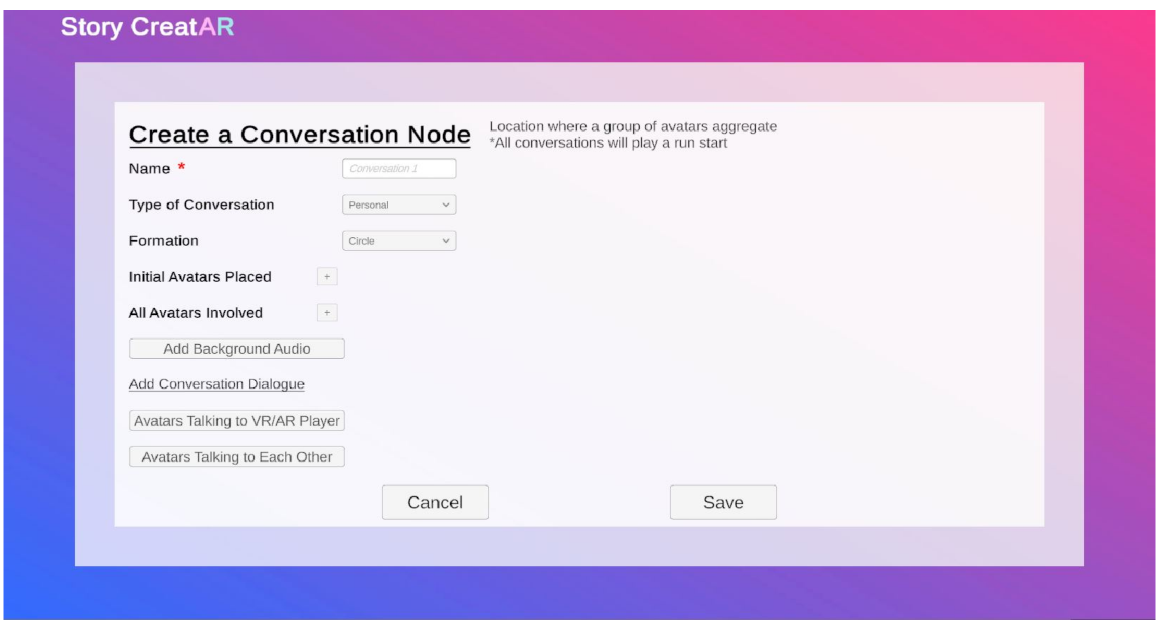

Figure B.17: Authors can create conversations by specifying a name, the distance between avatars, how they should be arranged, what avatars should be present, and what dialogues should be spoken.

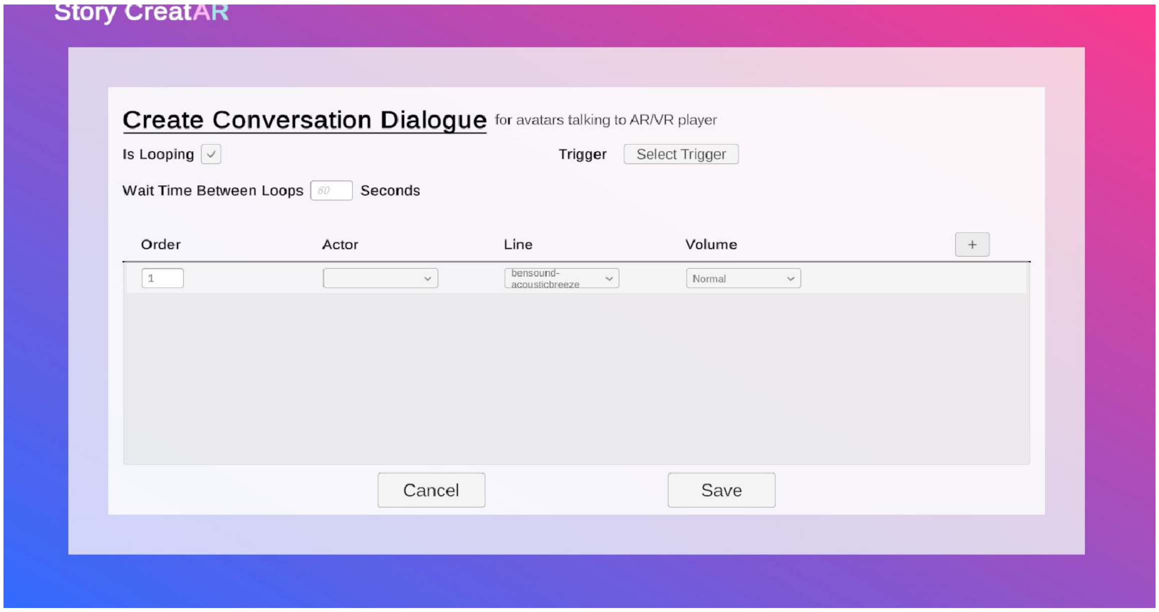

Figure B.18: Authors can specify if the conversation is looping, how long to wait between loops, the proxemic trigger, and the order of the dialogue line (who speaks it, the audio file, and the volume).

Figure B.19: Creating a distance rule for triggering a conversation.

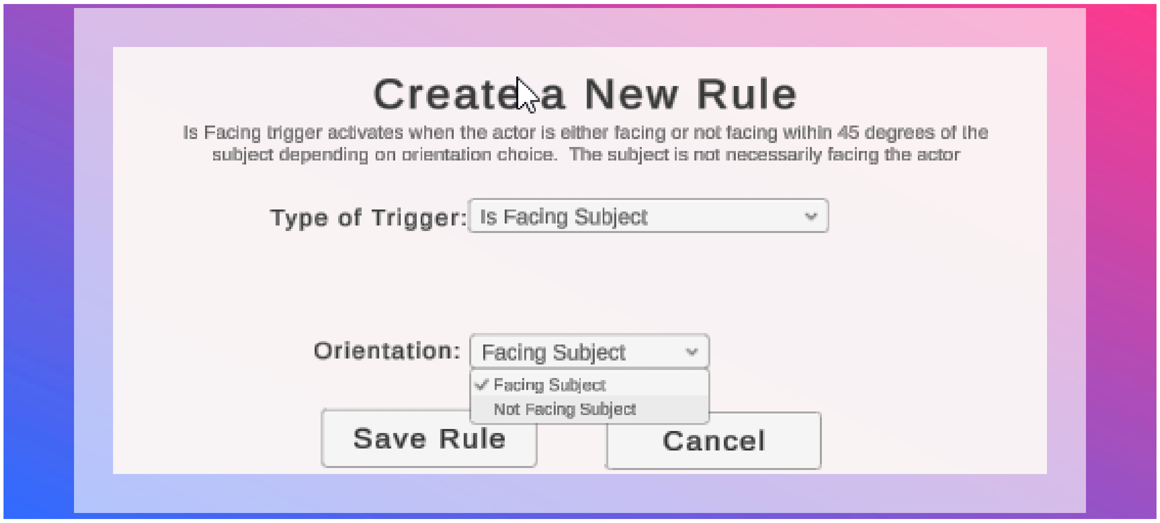

Figure B.20: Creating an is facing rule for triggering a conversation.

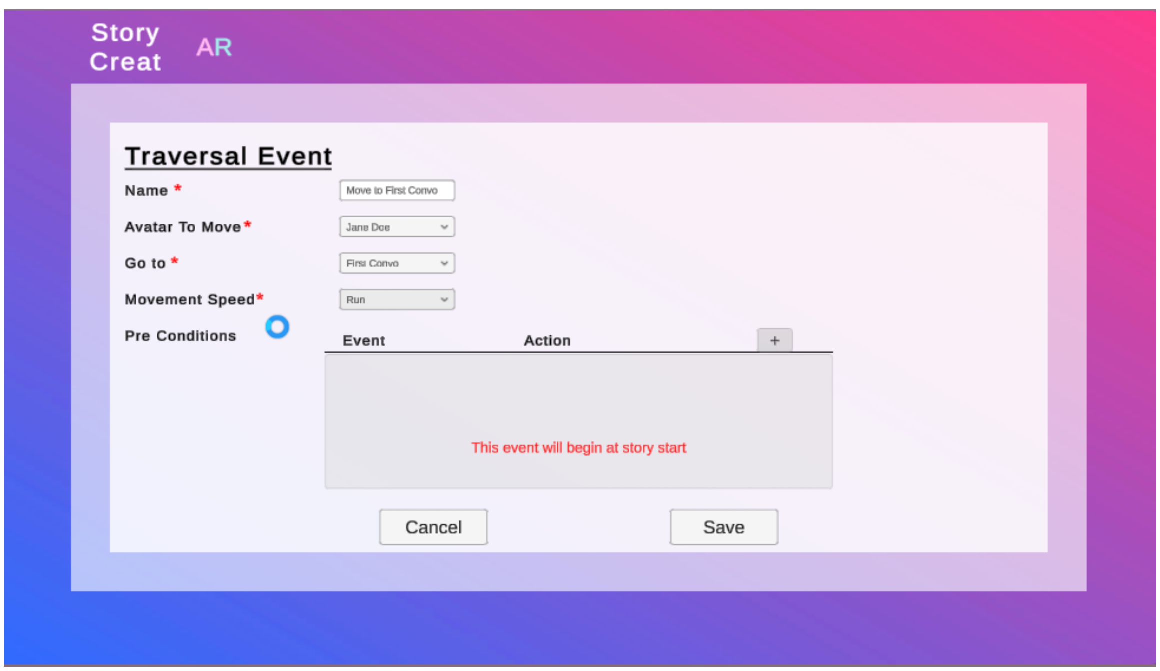

Figure B.21: Creating a traversal event

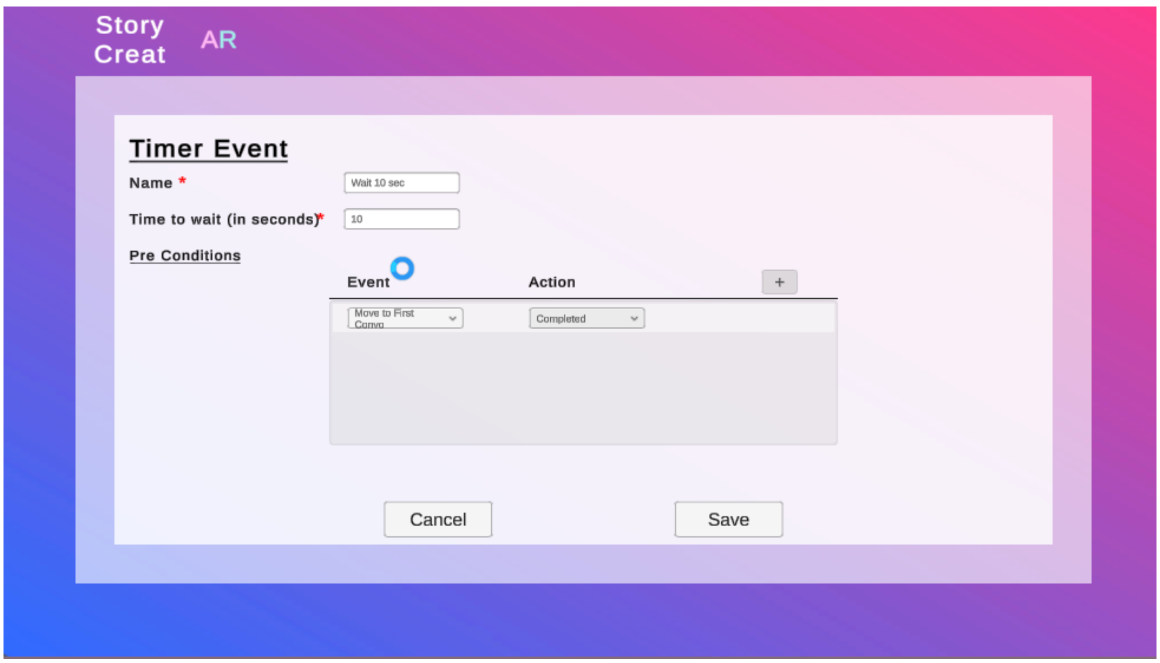

Figure B.22: Creating a timer event

Appendix C

Author Graph Representations

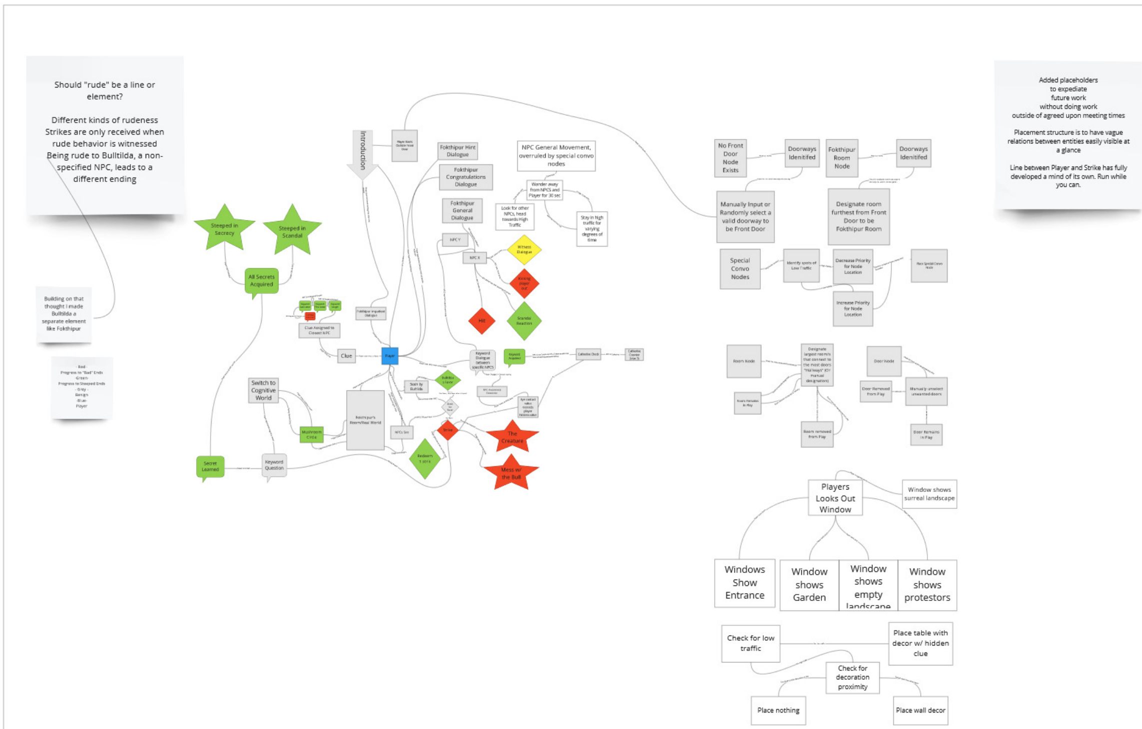

Figure C.1: Graph for Spill created by Ryan.

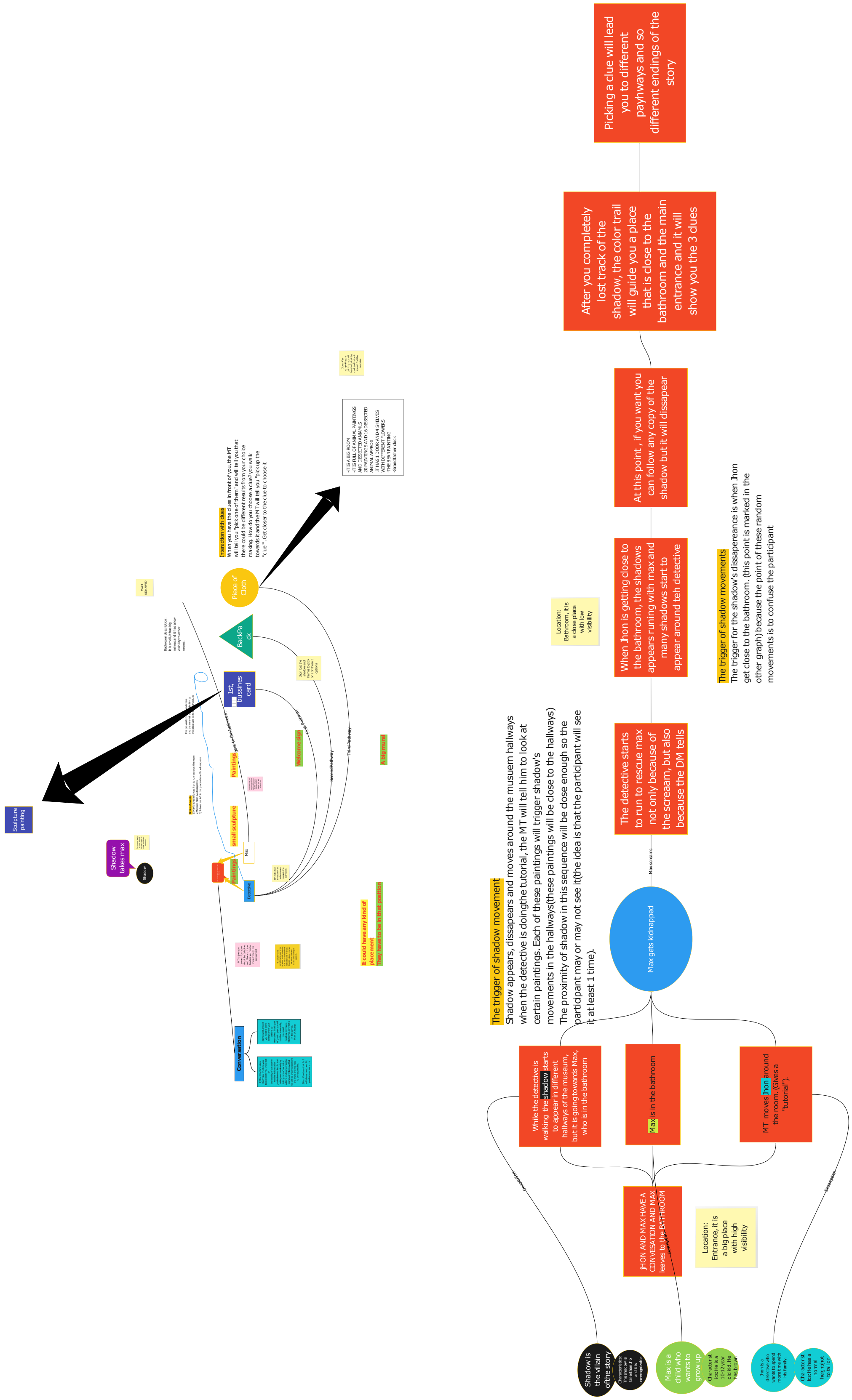

Figure C.2: Graph for Standville Museum created by Eric.

Figure C.3: Graph for Tyson's Peak created by Amy.

Appendix D

Affinity Diagram Summary for Graph and Interface Phases

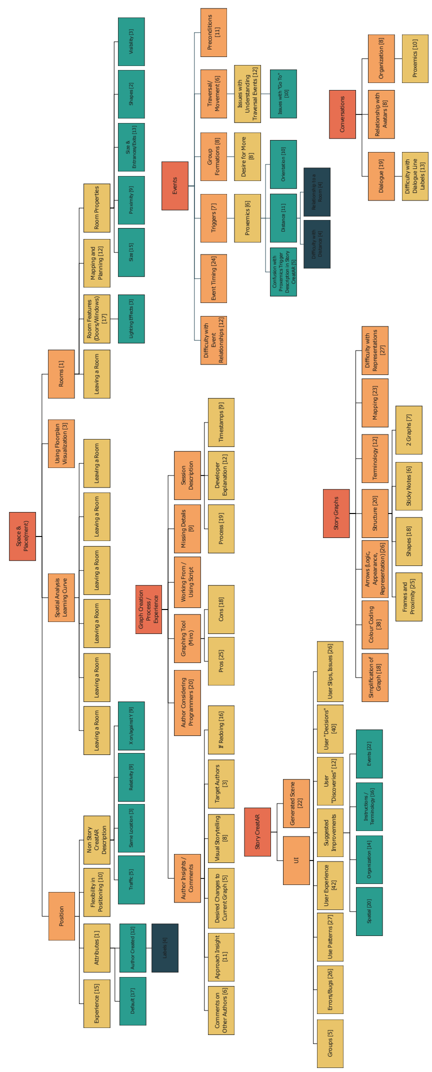

Figure D.1: Affinity Diagram Summary on Graph Creation and Interface Phases

Appendix E

REB — Author Participants in Story CreatAR Evaluation

E.1 Approval Letter

DALHOUSIE UNIVERSITY
Research Services

Social Sciences & Humanities Research Ethics Board
Amendment Approval

November 06, 2020

Mohammed Alnusayri
Computer Science\Computer Science

Dear Mohammed,

REB #: 2018-4522
Project Title: ProxemicUI: object-oriented middleware and event model for proxemics-aware applications on responsive interactive displays

The Social Sciences & Humanities Research Ethics Board has reviewed your amendment request and has approved this amendment request effective today, November 06, 2020.

Effective March 16, 2020: Notwithstanding this approval, any research conducted during the COVID-19 public health emergency must comply with federal and provincial public health advice as well as directives from Dalhousie University (and/or other facilities or jurisdictions where the research will occur) regarding preventing the spread of COVID-19.

Sincerely,

Dr. Karen Foster, Chair

E.2 Consent Form

Informed Consent for Author Participants in Story CreatAR

DALHOUSIE UNIVERSITY

ProxemicUI: object-oriented middleware and event model for proxemics-aware applications on responsive interactive displays

Investigators: Mohammed Alnusayri, Faculty of Computer Science

Dr. Derek Reilly, Faculty of Computer Science

Dr. Joseph Malloch, Faculty of Computer Science

Peter Haltner, Faculty of Computer Science

Abbey Singh, Faculty of Computer Science

Ramanpreet Kaur, Faculty of Computer Science

Matt Peachey, Faculty of Computer Science

Contact Person: Mohammed Alnusayri, Faculty of Computer Science, mh625076@cs.dal.ca

We invite you to take part in a research study being conducted by Mohammed Alnusayri at Dalhousie University. Your participation in this study is voluntary and you may withdraw from the study at any time. Your academic (or employment) performance evaluation will not be affected by whether or not you participate. To be eligible to participate in the study be 18 or older. The study is described below. You will directly benefit from participating in this research project by working with investigators to produce a version of a story you have authored as an interactive virtual reality experience, using an authoring toolkit called Story CreatAR. An indirect benefit is the opportunity to advance research knowledge and potentially benefit others.

The purpose of the study is to evaluate the benefit to authors of features integrated into the Story CreatAR toolkit. You will work on creating your stories using Story CreatAR in collaboration with the study investigators, who will provide authoring assistance and support as needed. You can withdraw from the study at any time without consequence.

The main investigator will have emailed you this informed consent form, which you should carefully review, sign, and email back.

During the study, we will collect data of about your usage of Story CreatAR and also ask for your feedback about the process of using the tool and its features. Collected data includes screen capture of collaborative authoring sessions, screen recordings of post-session interviews, design documents created during the authoring process, and copies of the script and resulting VR content. You will retain copies of all creative output. All personal and identifying data will be kept confidential in publication. Anonymity of textual data will be preserved by using pseudonyms to ensure your confidentiality. Audio and video capture will not be used in publication. Inclusion of creative materials (script elements, VR story) in publications will not occur without your explicit verbal consent. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance to University policy for three years post publication.

In the event that you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact Catherine Connors, Director, Office of Research Ethics Administration at Dalhousie University's Office of Human Research Ethics for assistance: phone: (902) 494-1462, email: Catherine.connors@dal.ca.

Appendix F

REB — Comparing Sharing Techniques in AR Narratives

F.1 Approval Letter

From: ethics@dal.ca
Sent: Friday, July 9, 2021 3:30 PM
To: Abbey Singh
Cc: Derek Reilly; Annie Laroche; Caroline Sequeira; Research Ethics
Subject: REB # 2021-5745 Letter of Approval

DALHOUSIE UNIVERSITY
Research Services

Social Sciences & Humanities Research Ethics Board
Letter of Approval

July 09, 2021
Abbey Singh
Computer Science\Computer Science

Dear Abbey,

REB #: 2021-5745
Project Title: Comparing Techniques for Sharing Building-Scale Augmented Reality Narratives

Effective Date: July 09, 2021
Expiry Date: July 09, 2022
The Social Sciences & Humanities Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans.* This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.

Effective March 16, 2020: Notwithstanding this approval, any research conducted during the COVID-19 public health emergency must comply with federal and provincial public health advice as well as directives from Dalhousie University (and/or other facilities or jurisdictions where the research will occur) regarding preventing the spread of COVID-19.
Sincerely,

Dr. Karen Foster, Chair

FUNDED
NSERC: RGPIN-2018-04584

F.2 Consent Form

Appendix A – Informed Consent for Nocturne Study

DALHOUSIE UNIVERSITY

Project title: Comparing Augmented Reality Shared Narrative Experiences

Investigators: Abbey Singh, Faculty of Computer Science
Dr. Derek Reilly, Faculty of Computer Science
Dr. Joseph Malloch, Faculty of Computer Science
Peter Haltner, Faculty of Computer Science
Ramanpreet Kaur, Faculty of Computer Science
Matt Peachey, Faculty of Computer Science
Shannon Frederick, Faculty of Computer Science
Dr. Shannon Brownlee, Fountain School of Performing Arts
Dr. Wallace Lages, School of Visual Arts, Virginia Tech
Thiago Porcino, Faculty of Computer Science
Hariprashanth Deivasigamani, Faculty of Computer Science
Contact Person: Abbey Singh, Faculty of Computer Science, ab541393@dal.ca

Introduction
We invite you to take part in a research study being conducted by, Abbey Singh, who is a master's student at Dalhousie University. Choosing whether to take part in this research is entirely your choice. To be eligible to participate in the study you must be over the age of 14 and not have any hearing, seeing, or physical disabilities that prevent you from optimally experiencing the content. If you are a student, there will be no impact on your studies if you decide not to participate in the research. The study is described below. You should discuss any questions you have about this study with Abbey Singh. Please ask as many questions as you like. You may benefit from this study by experiencing a novel narrative experience in AR. An indirect benefit is the opportunity to advance research in this area and to benefit authors in experiential media. The main purpose of this study is to evaluate shared immersive AR narrative experiences.

If you decide to participate in this research, you will be asked to experience one augmented reality story. The visit will take approximately 15 minutes, not including this informed consent. In the study, you will be experiencing one of two narratives: Standville Museum or Spill. The equipment will be appropriately cleaned according to HoloLens 2 COVID-19 cleaning regulations and provided for you to use during the study. We will oblige with Nova Scotia health and safety guidelines when applicable.

One of the investigators will have provided you with this informed consent form, which you should carefully review, and sign.

During the study, we will collect data on your experience with the story and ask for your feedback about the story experience using a questionnaire. Collected data includes your position during the experience, conversation with the other person experiencing the story with you, video recordings and observations during the story experience, your interactions with the story, and questionnaires. All personal and identifying data will be kept confidential in publication. Anonymity of textual data will be preserved by using IDs to ensure your confidentiality. Photo and video capture will only be used in publication if consent is provided and your face will be blurred. Video data will be stored on a secure networked attached storage. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance with University policy for three years post publication.

In the event that you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact Catherine Connors, Director, Office of Research Ethics Administration at Dalhousie University's Office of Human Research Ethics for assistance: phone: (902) 494-1462, email: Catherine.connors@dal.ca.

Project Title: Comparing Augmented Reality Shared Narrative Experiences

Lead Researcher: Abbey Singh, Faculty of Computer Science, ab541393@dal.ca

Participant	**Researcher**
Name: ______________________________	Name: ______________________________
Signature: ___________________________	Signature: ___________________________
Date: ______________________________	*Date:* ______________________________

The following aspects of your participation are **optional**. Please indicate your consent by **initialing** beside the item:

"*I agree to let you directly quote any comments or statements made in any written reports without viewing the quotes prior to their use and I understand that the anonymity of textual data will be preserved by using IDs.*"

Participant: __________ ***Researcher:*** __________

"*I agree to let you use photographs or video recordings during the study and I understand that the anonymity of visual data will be preserved by blurring my face.*"

Participant: __________ ***Researcher:*** __________

If you are interested in seeing the results of this study, please check below and provide your email address. We will contact you with publication details that describe the results.

"I would like to be notified by email when results are available via a publication."

[if this option is chosen, please include a contact email address:
______________________________]

Appendix G

REB — Comparing AR Narrative Placement Methods

G.1 Approval Letter

From: ethics@dal.ca
Sent: Tuesday, February 9, 2021 10:37 AM
To: Abbey Singh
Cc: Derek Reilly; Research Ethics
Subject: REB # 2020-5435 Letter of Approval

DALHOUSIE UNIVERSITY
Research Services

Social Sciences & Humanities Research Ethics Board
Letter of Approval

February 09, 2021
Abbey Singh
Computer Science\Computer Science

Dear Abbey,

REB #: 2020-5435
Project Title: Comparing Virtual/Augmented Reality Narrative Placement Methods: spatial analysis from Story CreatAR, Random Placement, and Manual Placement at two different locations

Effective Date: February 09, 2021
Expiry Date: February 09, 2022
The Social Sciences & Humanities Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans.* This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.

Effective March 16, 2020: Notwithstanding this approval, any research conducted during the COVID-19 public health emergency must comply with federal and provincial public health advice as well as directives from Dalhousie University (and/or other facilities or jurisdictions where the research will occur) regarding preventing the spread of COVID-19.
Sincerely,

Dr. Karen Foster, Chair

Post REB Approval: On-going Responsibilities of Researchers

G.2 Consent Forms

Informed Consent for Virtual Study

Project title: Comparing Virtual/Augmented Reality Narrative Placement Methods: spatial analysis from Story CreatAR, Random Placement, and Manual Placement at two different locations

Investigators: Abbey Singh, Faculty of Computer Science

Dr. Derek Reilly, Faculty of Computer Science

Dr. Joseph Malloch, Faculty of Computer Science

Peter Haltner, Faculty of Computer Science

Ramanpreet Kaur, Faculty of Computer Science

Matt Peachey, Faculty of Computer Science

Shannon Frederick, Faculty of Computer Science

Contact Person: Abbey Singh, Faculty of Computer Science, ab541393@dal.ca

Introduction

We invite you to take part in a research study being conducted by, Abbey Singh, who is a masters student at Dalhousie University. Choosing whether or not to take part in this research is entirely your choice. To be eligible to participate in the study you must be 16 years or older and not have any hearing, seeing, or physical disabilities that prevent you from optimally experiencing the content. If you are a student, there will be no impact on your studies if you decide not to participate in the research. The study is described below. You should discuss any questions you have about this study with Abbey Singh. Please ask as many questions as you like. You may benefit from this study by experiencing a novel narrative experience in VR. An indirect benefit is the opportunity to advance research in this area and to benefit authors in experiential media.

There are two main purposes of this study. The first is to evaluate the effectiveness of spatial analysis tools to place story content (e.g., a desk) in a building by comparing it to other methods (random placement, manual placement). The second is to compare a location that has high correspondence with spatial analysis (e.g., space syntax predictions of the number of people that pass through a door closely matches what occurs in the real world) and a location with low correspondence (prediction and observation is different).

If you decide to participate in this research, you will be asked to send an address where an Oculus Quest virtual reality headset can be dropped off and to attend one virtual meeting. The Oculus Quest will be cleaned according to COVID-19 health guidelines for cleaning a VR headset and other applicable health guidelines for Nova Scotia will be obliged. The meeting will take approximately 90 minutes. You will be experiencing three narratives (Tyson's Peak, Spill, and Standville Museum) using virtual reality.

The main investigator will have emailed you this informed consent form, which you should carefully review, sign, and email back. By signing this consent form you also agree to set-up a time (within one week upon request) where one researcher can pick-up the Oculus Quest headset from your location.

During the study, we will collect data on your experience with the three stories and ask for your feedback about the story experiences using interviews and questionnaires. Collected data includes video recordings and observations during the story experiences, the interviews, and questionnaires. All personal and identifying data will be kept confidential in publication. Anonymity of textual data will be preserved by using IDs to ensure your confidentiality. Photo and video capture will only be used in publication if consent is provided and your face will be blurred. Microsoft Teams routes audio and video recordings through the United States and these recordings are subject to the US Patriot Act and may be accessible to government and/or law enforcement for the duration of the interview. After the interview, the recordings are stored in Canada on a secure networked attached storage. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance with University policy for three years post publication.

In the event that you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact Catherine Connors, Director, Office of Research Ethics Administration at Dalhousie University's Office of Human Research Ethics for assistance: phone: (902) 494-1462, email: Catherine.connors@dal.ca.

Project Title: Comparing Virtual/Augmented Reality Narrative Placement Methods: spatial analysis from Story CreatAR, Random Placement, and Manual Placement at two different locations

Lead Researcher: Abbey Singh, Faculty of Computer Science, ab541393@dal.ca

Participant **Researcher**

Name: ______________________________ Name: ________________________________

Signature: ___________________________ Signature: _____________________________

Date: _______________________________ *Date:* ______________________________

The following aspects of your participation are optional please indicate your consent by initialing by the item:

"*I agree to let you directly quote any comments or statements made in any written reports without viewing the quotes prior to their use and I understand that the anonymity of textual data will be preserved by using IDs.*"

Participant: _________ ***Researcher:*** _________

"*I agree to let you use photographs or video recordings during the study and I understand that the anonymity of visual data will be preserved by blurring my face.*"

Participant: _________ ***Researcher:*** _________

If you are interested in seeing the results of this study, please check below and provide your email address. We will contact you with publication details that describe the results *"I would like to be notified by email when results are available via a publication."* [if this option is chosen, please include a contact email address: ________________________________]

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Informed Consent for In-person Study

Project title: Comparing Virtual/Augmented Reality Narrative Placement Methods: spatial analysis from Story CreatAR, Random Placement, and Manual Placement at two different locations

Investigators: Abbey Singh, Faculty of Computer Science
Dr. Derek Reilly, Faculty of Computer Science
Dr. Joseph Malloch, Faculty of Computer Science
Peter Haltner, Faculty of Computer Science
Ramanpreet Kaur, Faculty of Computer Science
Matt Peachey, Faculty of Computer Science
Shannon Frederick, Faculty of Computer Science
Contact Person: Abbey Singh, Faculty of Computer Science, ab541393@dal.ca

Introduction
We invite you to take part in a research study being conducted by, Abbey Singh, who is a masters student at Dalhousie University. Choosing whether or not to take part in this research is entirely your choice. To be eligible to participate in the study you must be 16 years or older and not have any hearing, seeing, or physical disabilities that prevent you from optimally experiencing the content. If you are a student, there will be no impact on your studies if you decide not to participate in the research. The study is described below. You should discuss any questions you have about this study with Abbey Singh. Please ask as many questions as you like. You may benefit from this study by experiencing a novel narrative experience in AR. An indirect benefit is the opportunity to advance research in this area and to benefit authors in experiential media.

There are two main purposes of this study. The first is to evaluate the effectiveness of spatial analysis tools to place story content (e.g., a desk) in a building by comparing it to other methods (random placement, manual placement). The second is to compare a location that has high correspondence with spatial analysis (e.g., space syntax predictions of the number of people that pass through a door closely matches what occurs in the real world) and a location with low correspondence (prediction and observation is different).

If you decide to participate in this research, you will be asked to attend one visit at the University Campus. The visit will take approximately 90 minutes. In the study, you will be experiencing three narratives (Tyson's Peak, Spill, and Standville Museum) at one of the two selected locations using AR. The equipment will be appropriately cleaned according to HoloLens COVID-19 cleaning regulations and provided for you to use during the study. We will oblige with Nova Scotia health guidelines for public gatherings when applicable.

The main investigator will have emailed you this informed consent form, which you should carefully review, sign, and email back.

During the study, we will collect data on your experience with the three stories and ask for your feedback about the story experiences using interviews and questionnaires. Collected data includes video recordings and observations during the story experiences, the interviews, and questionnaires. All personal and identifying data will be kept confidential in publication. Anonymity of textual data will be preserved by using IDs to ensure your confidentiality. Photo and video capture will only be used in publication if consent is provided and your face will be blurred. Video data will be stored on a secure networked attached storage. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance with University policy for three years post publication.

In the event that you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact Catherine Connors, Director, Office of Research Ethics Administration at Dalhousie University's Office of Human Research Ethics for assistance: phone: (902) 494-1462, email: Catherine.connors@dal.ca.

Project Title: Comparing Virtual/Augmented Reality Narrative Placement Methods: spatial analysis from Story CreatAR, Random Placement, and Manual Placement at two different locations

Lead Researcher: Abbey Singh, Faculty of Computer Science, ab541393@dal.ca

Participant **Researcher**
Name: ______________________________ Name: ________________________________

Signature: ___________________________ Signature: ______________________________

Date: ______________________________ *Date:* ______________________________

The following aspects of your participation are optional please indicate your consent by initialing by the item:

"*I agree to let you directly quote any comments or statements made in any written reports without viewing the quotes prior to their use and I understand that the anonymity of textual data will be preserved by using IDs.*"

Participant: _________ ***Researcher:*** _________

"*I agree to let you use photographs or video recordings during the study and I understand that the anonymity of visual data will be preserved by blurring my face.*"

Participant: _________ ***Researcher:*** _________

If you are interested in seeing the results of this study, please check below and provide your email address. We will contact you with publication details that describe the results
"I would like to be notified by email when results are available via a publication."
[if this option is chosen, please include a contact email address:
________________________________]
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