HAW HAMBURG

MASTER'S THESIS

Narration and Impossible Spaces: The Influence of Storytelling on Spatial Perception in Virtual Reality

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Abstract

Virtual Reality can let users experience environments that would not be possible in a real world setting. One approach to extending the limited physical space virtually is the use of Impossible Spaces, such as overlapping virtual rooms. This thesis investigates whether storytelling influences the perception of such spatial inconsistencies.

A between-subjects user study with 20 participants was conducted. The participants experienced the same VR environment with three overlapping rooms, identical tasks, interactions, and task-relevant information. The main difference between the two conditions was the narrative framing of the information that was provided via audio. One group experienced a coherent science-fiction story, while the other received functional information without explicit narrative framing.

The results did not support the proposed hypotheses. Presence was not higher in the storytelling condition, the direct detection rate of the spatial overlap was identical in both groups, and the perceived disturbance of detected inconsistencies did not differ significantly between conditions.

Overall, the findings provide no clear evidence that storytelling alone increased presence or reduced the detection or disturbance of Impossible Spaces in the implemented VR experience. The results suggest that spatial perception may instead depend on a combination of narrative context, attention, task demands, audio information, and spatial design.

Contents

List of Figures IV

List of Tables V

List of Abbreviations VI

1. Introduction 1
- 1.1. Motivation and Problem Statement . . . 2
- 1.2. Aim of the Thesis . . . 2
- 1.3. Research Questions . . . 3
- 1.4. Thesis Structure . . . 3

2. Theoretical Background and Related Work 4
- 2.1. Spatial Perception and Natural Walking . . . 4
- 2.2. Presence and Immersion . . . 5
- 2.3. Impossible Spaces . . . 6
- 2.4. Factors Influencing the Detection of Impossible Spaces . . . 7
  - 2.4.1. Spatial Factors: Overlap, Layout, Corridors, and Occlusion . . . 8
  - 2.4.2. Attention, Distraction, and Cognitive Load . . . 9
- 2.5. Storytelling and Narration . . . 9
  - 2.5.1. Characteristics and Spatial Storytelling . . . 10
  - 2.5.2. Attention, Presence, and Engagement . . . 11
- 2.6. Narrative Context and Impossible Spaces . . . 12
- 2.7. Research Gap . . . 13

3. Design and Implementation of the VR Application 15
- 3.1. Design Goals and Requirements . . . 15
- 3.2. Virtual Environment and Spatial Layout . . . 16
- 3.3. Tasks and Interactions . . . 17
- 3.4. Experimental Conditions . . . 18
  - 3.4.1. Storytelling Condition A . . . 18
  - 3.4.2. Non-Storytelling Condition B . . . 19

3.5. Technical Implementation . . . 19
3.5.1. Assets and Audio Production . . . 20
3.5.2. Data Logging . . . 20

4. Methodology **21**
4.1. Study Design . . . 21
4.2. Participants . . . 21
4.3. Experimental Setup . . . 22
4.4. Procedure . . . 22
4.5. Measures . . . 23
4.5.1. Background Information . . . 23
4.5.2. Simulator Sickness Questionnaire . . . 23
4.5.3. Igroup Presence Questionnaire . . . 24
4.5.4. NASA Raw-TLX . . . 24
4.5.5. Study-Specific Measures . . . 24
4.5.6. Behavioral Timing Measures . . . 26
4.6. Data Analysis . . . 26

5. Results **28**
5.1. Sample and Data Overview . . . 28
5.2. Manipulation Check . . . 28
5.3. Main Hypothesis Results . . . 30
5.3.1. Presence (H1) . . . 30
5.3.2. Detection of Spatial Inconsistencies (H2) . . . 31
5.3.3. Perceived Disturbance (H3) . . . 32
5.4. Additional Measures . . . 33
5.4.1. Attention, Audio, Task Load, and Urgency . . . 33
5.4.2. Experience Duration . . . 33
5.4.3. Spatial Experience . . . 34
5.4.4. Simulator Sickness . . . 34
5.4.5. Prior Experience . . . 36

6. Discussion **37**
6.1. Storytelling and Presence . . . 37
6.2. Storytelling and Detection of Impossible Spaces . . . 38
6.3. Perceived Disturbance of Impossible Spaces . . . 38
6.4. Interpretation of the Narrative Manipulation . . . 39
6.5. Limitations . . . 40
6.6. Implications and Future Work . . . 40

7. Conclusion **42**

Bibliography 44

A. Audio Scripts 47

B. Questionnaire 51

C. Supplementary Results 57
C.1. Study-Specific Questionnaire Measures 57
C.2. Simulator Sickness Questionnaire 58
C.3. Additional Spatial and Detection Measures 58
C.4. Behavioral Timing Measures 58

List of Figures

3.1. Spatial layout and room overlap 16
3.2. VE rooms overview 17

List of Tables

4.1. Study-specific measures 25

5.1. Sample characteristics by experimental condition. 29
5.2. Narrative manipulation-check ratings by condition. 30
5.3. Presence measures by experimental condition. 31
5.4. Detection and disturbance of spatial inconsistencies by condition. 32
5.5. Descriptive timing measures by experimental condition. 34
5.6. Descriptive results for additional questionnaire measures. 35

A.1. Audio scripts of both experimental conditions 47

B.1. Questionnaire used in the study 51

C.1. Supplementary questionnaire results 57
C.2. Supplementary SSQ results 58
C.3. Supplementary spatial and detection results 58
C.4. Participant-level timing measures 58

List of Abbreviations

HMD Head-Mounted Display.

IPQ Igroup Presence Questionnaire.

IS Impossible Spaces.

NASA-TLX National Aeronautics and Space Administration - Task Load Index.

SDK Software Development Kit.

SSQ Simulator Sickness Questionnaire.

TTS text-to-speech.

VE Virtual environment.

VR Virtual Reality.

1. Introduction

Virtual Reality (VR) offers a wide range of possibilities when it comes to experiencing environments and situations that would not be possible in a real-world context. This can mean experiencing fictional worlds and interacting with made-up objects, or even the types of movement used for navigating these environments. Natural walking, in particular, can enhance the user's feeling of actually being located in a virtual environment. It can provide an intuitive form of locomotion because users can move through the virtual environment in a similar way to how they move through the real world (Ojha et al., 2025; Rebelo et al., 2025). The available physical tracking area can limit natural walking because virtual environments can theoretically extend beyond the available physical space, while a physical area is restricted to the available space in the real world (Rebelo et al., 2025; Suma et al., 2012).

Different techniques have been developed to utilize the limited available space in a way that provides a larger virtual space, for example, redirected walking or manipulations of the virtual environment (Suma et al., 2012; Vasylevska & Kaufmann, 2017). One of these techniques is the use of so-called Impossible Spaces (Suma et al., 2012), such as overlapping virtual rooms. Overlapping virtual rooms can occupy the same physical real-world space without the user necessarily noticing the overlap. If the spatial inconsistency remains unnoticed or does not negatively affect the experience, this technique can allow a larger virtual environment to be experienced within a smaller physical area (Suma et al., 2012). Previous research has shown that the perception of these overlapping rooms can be influenced by the layout, corridors, visual information, and distractions (C. Ciumedean et al., 2021; C.-B. Ciumedean et al., 2020; Suma et al., 2012; Vasylevska & Kaufmann, 2017). It has also been shown that attentional demands and additional tasks can influence the detection of spatial manipulations (C.-B. Ciumedean et al., 2020; Vasylevska & Kaufmann, 2017). That raises the question of whether narration or storytelling can also influence, or to what degree it can influence, the perception of Impossible Spaces in the form of self-overlapping rooms.

In many VR applications, users not only navigate through an environment but also listen to dialogue, complete tasks, and take on roles within a story. Narrative design and audiovisual cues can be used to guide the user's attention within a virtual experience (Arcagni & D'Aloia, 2021). Storytelling could influence Impossible Spaces in different ways. It could shift attention away from the spatial layout, which could make the detection of spatial inconsistencies less likely. It could also make spatial inconsistencies feel more coherent or acceptable within the

overall experience, an idea that is related to previous work integrating Impossible Spaces into narrative contexts (Fisher et al., 2017). The relationship between storytelling and the perception of Impossible Spaces is the main focus of this thesis.

1.1. Motivation and Problem Statement

The available physical space is a major limitation when it comes to room-scale VR and natural walking. Impossible Spaces can help with that limitation (Suma et al., 2012). However, this technique is most effective when users do not notice spatial inconsistencies or when their experience is not negatively impacted. Previous studies have shown that distractions can impact the detection of overlapping rooms (C.-B. Ciumedean et al., 2020). Storytelling is often used in VR applications, and previous work has investigated how geometric factors, overlap ratios, corridor layouts, visual occlusion, and attentional distraction affect the detection of Impossible Spaces (C. Ciumedean et al., 2021; C.-B. Ciumedean et al., 2020; Suma et al., 2012; Vasylevska & Kaufmann, 2017). Although previous work has integrated Impossible Spaces into a narrative context (Fisher et al., 2017), the specific influence of storytelling on the detection and perception of Impossible Spaces has received little direct investigation. Therefore, it is relevant to investigate whether a narrative makes spatial inconsistencies less noticeable or less disturbing, and whether the narrative context affects the sense of presence.

1.2. Aim of the Thesis

The aim of this thesis is to investigate the influence of storytelling on the perception of Impossible Spaces in VR. For this purpose, two versions of the same VR environment are compared in a between-subjects study. Group A experiences the environment with a coherent story, while Group B receives only the information required to complete the tasks without additional narrative context. The spatial environment remains the same, with identical tasks and the same basic interactions. Both groups receive the same information regarding the tasks, with the main difference being the narrative framing of the information they receive. The length of the received audio remained similar. The main focus is on whether storytelling affects the sense of presence, whether it changes the detection of spatial inconsistencies, and whether detected inconsistencies are perceived as less disturbing when encountered in a narrative context. This thesis aims to provide a better understanding of whether a narrative context influences the perception and experience of spatial manipulations in VR by comparing a storytelling version and a non-storytelling version of the same Impossible Space environment.

1.3. Research Questions

Based on the motivation and the research gap, this thesis investigates how narration influences the perception of Impossible Spaces in Virtual Reality. The first research question asks how narration affects the perception of Impossible Spaces (**RQ1**). The second research question asks whether a narrative context increases the sense of presence in Virtual Reality (**RQ2**). This question is based on the assumption that a narrative context may influence how present users feel in the virtual environment. The third research question investigates whether spatial inconsistencies are less noticeable when they are integrated into a narrative context (**RQ3**). The idea is based on the assumption that storytelling may direct attention away from the environment's spatial layout.

The hypotheses derived from these research questions are presented in Chapter 2 after the relevant theoretical background and previous research have been discussed.

1.4. Thesis Structure

Following is a brief overview of the structure and order of the remaining thesis. Chapter 2 presents the theoretical background and related work on Impossible Spaces, spatial perception, presence, and storytelling. Chapter 3 explains the design and implementation of the VR application used for the study, including the virtual environment, the spatial layout, and the tasks and interactions in detail. The two experimental conditions, storytelling and non-storytelling, will also be presented. Chapter 4 explains the methodology of the user study, including participants, the experimental setup and procedure, as well as questionnaires, additional measures, and data analysis. Chapter 5 presents the results of the conducted study. Chapter 6 interprets and discusses the results in regard to the research questions, hypotheses, and previous work. Chapter 7 summarizes and concludes the main findings and gives an outlook on future work.

2. Theoretical Background and Related Work

How users experience a virtual environment and move through it can be influenced by the spatial perception of the virtual environment. This section introduces spatial perception and natural walking and then discusses presence and immersion.

2.1. Spatial Perception and Natural Walking

Spatial perception and navigation form the basis for understanding virtual environments. It is important for users to understand their own position and orientation within the virtual environment, which includes the perception of distances, directions, landmarks, and spatial relationships between different areas. Navigation in VR consists not only of physical movement but also of a cognitive process. Navigation can be divided into wayfinding and travel. Travel refers to the actual movement from one location to another. Wayfinding refers to the cognitive processes that guide this movement, such as understanding the current location, forming a mental representation of the environment, and planning a path toward a destination (Jerald, 2015). Wayfinding, therefore, relies on environmental cues, landmarks, attention, and memory to support orientation within an environment (Jerald, 2015).

Natural walking represents a very direct locomotion technique in which the user's physical movement is directly represented as movement in the virtual environment. This provides a strong correspondence between real-world and virtual movement, as well as high interaction fidelity compared to controller-based locomotion. Natural walking provides a direct and intuitive form of movement through the VE because the locomotion resembles walking in the real world (Jerald, 2015).

Suma et al. (2012) summarize previous research reporting that natural walking provides benefits for spatial orientation, navigation, search performance, presence, and attention.

Natural walking includes visual information, proprioceptive information, and vestibular information. Artificial locomotion, like joystick movement, creates a mismatch. The visual system indicates movement, while the body or vestibular system does not experience the

corresponding movement. A previous study compared locomotion using a joystick, teleportation, and redirected walking. Teleportation and redirected walking were preferred over joystick movement, while redirected walking performed best regarding the unconscious acquisition of spatial knowledge. Presence (see 2.2) was numerically higher for redirected walking but not significantly. Overall, the results suggest that the locomotion method may influence the gain of spatial knowledge (Langbehn et al., 2018).

The main limitation of natural walking is that physical movement is restricted by the size of the available real-world area. Once the dimensions of the virtual environment exceed the available real space, it can no longer be explored through 1:1 walking. This limits the size of virtual environments that can be explored only by natural walking (Jerald, 2015). This has motivated the development of techniques that allow users to physically walk through environments that are larger than their real surroundings. Approaches to redirection include manipulating the mapping between the physical and virtual movement, as well as manipulating the properties of the virtual environment itself. Redirected walking aims to enable users to physically walk through virtual environments that are larger than the available tracking space. Broadly, redirection can be achieved either by manipulating the mapping between real and virtual movement or by manipulating the properties of the virtual environment itself, including its architecture (Nilsson et al., 2018, Suma et al., 2012).

The term Impossible Spaces (IS) was introduced to address the conflict between natural walking and limited physical space. Impossible Spaces can be used in the form of self-overlapping virtual architecture to compress a larger virtual environment into a smaller physical space (Suma et al., 2012).

2.2. Presence and Immersion

There is a distinction between immersion and presence. Immersion is more strongly related to the VR system and the presented experience, whereas presence refers to the subjective psychological experience of actually being located within the virtual environment. A simple description of presence is a sense of “being there” (Jerald, 2015). Immersion depends on several properties of the VR experience, such as extensiveness, matching, surroundness, vividness, interactability, and plot. Jerald (2015) includes the “plot” as part of the immersion and relates it to the message, unfolding events, and behavior of the virtual world and its entities.
Natural walking can be a possible contributor to presence, as it provides a stronger correspondence between real bodily movement and virtual movement. Previous work found higher subjective presence for walking-based locomotion than for flying, while differences

between real walking and walking-in-place were less consistent (Usoh et al., 1999). In regard to presence and spatial manipulation, an additional question is whether impossible or dynamically changing spatial structures affect the feeling of being inside the VE. For example, a recent overlapping spaces study found no significant difference in the igroup presence questionnaire(IPQ) presence scores between their procedural overlapping maze and a spatially equivalent static maze (Ojha et al., 2025).

Natural walking provides a close correspondence between physical and virtual movement, but it is limited by the available physical space. This motivates spatial manipulation techniques such as Impossible Spaces.

2.3. Impossible Spaces

Virtual environments are often much larger than the available tracking area, which is why natural walking is difficult to support over larger environments. One approach to overcoming this problem is the manipulation of the virtual environment through architectural changes (Suma et al., 2012). Suma et al. (2012) first introduced the term Impossible Spaces in 2012. Impossible Spaces are defined as virtual environments containing spatial relationships that cannot physically exist in Euclidean real-world geometry. For example, self-overlapping architecture occurs when two or more virtual rooms occupy parts of the same physical tracking area. That way, larger virtual spaces are effectively compressed into smaller real spaces (Suma et al., 2012, Rebelo et al., 2025). The present thesis focuses specifically on indoor self-overlapping architecture, in which adjacent virtual rooms share a physical space.

Impossible Spaces rely on the fact that the user does not perceive all overlapping areas simultaneously. Depending on where the user is, the environment can switch between spatial states, meaning that, for example, one room becomes hidden while another becomes visible. The resulting layouts of these VEs are globally impossible but locally believable (Suma et al., 2012). One of the most common goals of Impossible Spaces is to keep the noticeability of the manipulation to a minimum. Compared with movement manipulation, the scene itself changes rather than distorts the user's physical-to-virtual movement mapping. The potential advantage is the preservation of the 1:1 movement within the currently visible space (Suma et al., 2012, Vasylevska and Kaufmann, 2017). The overlapping rooms can be connected using different methods. Rebelo et al. (2025) recently compared portals, corridors, and central hubs for connecting overlapping rooms within a 2.5 m × 2.5 m tracking space. All three techniques were found to be viable, with no significant differences in presence, spatial awareness, orientation, or general user-experience ratings. However, participants using corridors required more time to complete the task than those who used portals or central hubs. Another study compared natural walking in Impossible Spaces with teleportation,

joystick movement, and arm-swinging. They showed that natural walking had significantly higher immersion than teleportation and joystick movement, and higher usability than joystick movement and arm-swinging (Lochner and Gain, 2021).

A central question is to what extent virtual rooms can overlap before users notice that the layout is physically impossible. Even though one of the goals of overlapping architecture is to avoid detection, it was found that noticeable overlap did not necessarily cause users to perceive the spatial distances as compressed (Suma et al., 2012). Suma et al. (2012) showed in a fixed room condition that smaller rooms could overlap by up to approximately 56% before participants reliably detected the manipulation, which demonstrates that substantial spatial overlap can remain undetected. In an expanding room condition, they showed that larger rooms filling the available tracking space produced a lower threshold of approximately 31%. That suggests that overlap detectability depends on the characteristics of the environment. Even when the overlap became noticeable, participants' distance judgments between targets in adjacent rooms did not necessarily decrease in proportion to the spatial overlap. In other words, the perceived relationship between the rooms did not directly correspond to the physically overlapping layout (Suma et al., 2012).

Spatial perception can also be examined through how participants mentally reconstruct room positions. This raises not only the question of whether a participant detected an overlap, but also where they think the prior room was located, how far apart they perceived the rooms, and how the spatial layout was represented mentally (Vasylevska and Kaufmann, 2017).

Previous research showed that a significant amount of overlap can remain unnoticed. However, there is no universal detection threshold. The detection of overlapping spaces depends on different variables of the spatial configuration. The following section considers these factors.

2.4. Factors Influencing the Detection of Impossible Spaces

Even though it is an important factor, the perception of Impossible Spaces is influenced by more than just the amount of spatial overlap. Previous work has examined the properties of the spatial layout and factors related to the user's attention, which are discussed in this section.

2.4.1. Spatial Factors: Overlap, Layout, Corridors, and Occlusion

Previous research has identified several factors that can affect the detection of Impossible Spaces. The overlap percentage is an important factor. Larger overlaps generally increase the chance of detecting overlapping rooms. As shown in Suma et al. (2012), the exact limit depends on the context, with the results indicating detection thresholds of approximately 56% and 31%. The reported thresholds vary across different room configurations and implementations, suggesting that there is no single, universal overlap threshold. The navigation path can also potentially affect perception. Therefore, the detection threshold should be understood as dependent on the study configuration rather than as a fixed property of human perception. Vasylevska and Kaufmann (2017) presented a study with two identical 3 m × 4 m rooms with a deliberately fixed overlap of 50%. The purpose was to hold the overlap constant while investigating the effects of path and layout characteristics independently. They investigated different layout properties, such as the number of turns, the locations of corridor endpoints and doors relative to the overlap area, the sequence of left and right turns, symmetry and asymmetry, and walking direction.

Corridors can influence the perceived relationships between rooms. A corridor is not only a technical connector. The path traveled between rooms can affect a user's estimation of direction, distance, and relative room position. Earlier work has examined path complexity concerning differences in path length and the number of turns. Additional path length alone did not significantly affect overlap identification, as no significant difference was found between the shorter and longer U-shaped corridors. In contrast, the more complex C-shaped corridor, with more path length and additional turns, significantly reduced the chance of rooms being identified as overlapping (Vasylevska and Kaufmann, 2015).

A study by Vasylevska and Kaufmann (2017) examined whether the number and sequence of turns, such as different U-, J-, C-, G-, P-, and S-like path structures with different turning directions, influence the perceived spatial relationships. They also examined the door positions. The entrances and exits were positioned differently relative to the overlap area. Their results indicate that the endpoint position can contribute to distortions in the perceived relative position of the rooms, although the effect differed between layouts. Vasylevska and Kaufmann (2017) also compared curved and right-angled corridors. Their results suggest that smooth, curved corridors can provide additional benefits for spatial compression. Occlusion is also an important mechanism when it comes to the detection of overlapping rooms. Spatial changes can be hidden when the affected part of the environment is outside the user's current field of view. This prevents a direct visual comparison between the previous and updated spatial states (Vasylevska et al., 2013).

Vasylevska et al. (2013) introduced Flexible Spaces, where the room areas function as the main content spaces and the connecting spaces function as transitions. The spatial reconfiguration

takes place while users move between them. Corridors have also been used as transition areas between overlapping rooms in recent studies (Rebelo et al., 2025).

2.4.2. Attention, Distraction, and Cognitive Load

Attentional factors can also influence the detection of Impossible Spaces. C.-B. Ciumedean et al. (2020) investigated whether distractors could draw attention away from the spatial layout of the rooms. They conducted a test where participants moved between potentially overlapping rooms. A challenge-based distractor was placed in the connecting corridor. The distractor was designed to fit naturally into the prison scenario of the study and to draw attention away from the spatial relationship between the rooms. This way, the authors wanted to add additional cognitive load and make the participants less likely to pay attention to the distance covered between rooms. It was shown that, with a distractor, participants tolerated substantially larger overlaps before reliably perceiving the environment as impossible (C.-B. Ciumedean et al., 2020). The detection threshold increased from approximately 40% overlap without distractors to 67.8% with distractors (C.-B. Ciumedean et al., 2020). The majority of the participants also explicitly described the distractor condition as more demanding, which supports the idea that cognitive demand may contribute to lower detection. However, the authors explicitly caution against interpreting cognitive load as the only cause. A distractor could also change the urgency, suspense, affective state, movement speed, and time spent in a corridor (C.-B. Ciumedean et al., 2020).

Previous work showed that attention is a relevant factor when it comes to the detection of Impossible Spaces. Unlike a simple distractor, the narrative context may additionally influence how users interpret their roles, actions, and environment.

2.5. Storytelling and Narration

Storytelling or narration can go beyond sharing simple information through speech or writing. It can convey a narrative context about the setting, events or background, characters, the user's role, goals or motivations, the relationships between events or actions, and the progression through the experience. In VR, this can be combined with the virtual space, interactions, or user movement (Kazlauskaitė, 2025, Arcagni and D'Aloia, 2021). Bucher (2018) explains that traditional storytelling structures can still be useful in VR but need to be adapted to the spatial and interactive nature. The user's role within the virtual world must be considered because users can explore and experience the environment rather than only observe a predefined sequence.

2.5.1. Characteristics and Spatial Storytelling

VR storytelling differs from traditional screen-based storytelling. While traditionally the user looks at a fixed frame in a VR setting, they can be surrounded by a narrated environment. Users have the ability to freely turn their heads and bodies to explore their surroundings. The traditional cinematic control over the framing is substantially reduced, which poses the need for storytelling approaches suited specifically to VR (Arcagni and D'Aloia, 2021). The narrative experience is connected to spatial exploration, meaning the story is not necessarily experienced only through a linear sequence of presented images. The user physically inhabits and explores the environment, and the interaction with spatial possibilities or limitations contributes to the narrative experience. User movement and actions are also part of the experience. The body is not only the interface for navigation and interaction, but it is also involved in how the story is experienced (Arcagni and D'Aloia, 2021). Kazlauskaitė (2025) uses the concept of storyliving to emphasize that users experience a VR narrative from within the virtual storyworld rather than only observing it from the outside. Depending on the VR experience, the user can make choices, interact with characters, and influence elements of the environment (Kazlauskaitė, 2025). Kazlauskaitė (2025) characterizes VR as spatial, embodied, interactive, multisensory, affective, and user-oriented, and presents four dimensions for analyzing VR storyworlds: "Where am I?" refers to the setting and spatial context, "Who am I?" to the user's role and perspective, "Who am I with?" to relationships with other characters, and "What am I doing?" to the actions performed within the storyworld.

The VE itself can act as a narrative medium by carrying narrative information. The story is not only restricted to dialogue. The layout, objects, and visual design can contribute to narrative understanding. The movement through a space can aid the narrative progression. Entering new areas of a VE can correspond to new narrative information or a new stage of a story. That way, a spatial sequence can become part of a narrative sequence (Jang et al., 2023). Jang et al. (2023) described the VR space as a form of "writing space," with the narrative meaning organized at three levels: the architecture of the overall space, a collection or group of content, and individual objects or artifacts. These three levels work together to support "meaning-making" (Jang et al., 2023). A related perspective from video game research suggests that the space in games is not only a backdrop. The game space itself can communicate a narrative. Player exploration contributes to the construction of meaning (Attademo, 2023). Han et al. (2023) presented an architectural narrative VR approach in which the environment dynamically adapts its architecture according to the content sequence and user behavior.

2.5.2. Attention, Presence, and Engagement

While traditional storytelling can control what a viewer sees, a VR user can turn their head or body away from the point of interest. This may lead to events occurring outside the current field of view and raise the risk of important information being missed. To avoid this, the user can be directed toward the relevant narrative content using sound, visual elements, graphic cues, and environmental design (Arcagni and D'Aloia, 2021). User actions can also contribute to how the narrative is experienced. This suggests that a narrative role can provide meaning to an otherwise purely functional task. This allows the user to become an actor within the story instead of just being an observer (Kazlauskaitė, 2025). Sound is very relevant for attention in VR because it can direct users toward the narrative content without requiring them to visually fixate on a specific object (Arcagni and D'Aloia, 2021). Therefore, auditory narration may influence how attention is distributed between the narrative information, the current tasks, and the surrounding spatial environment.

A narrative context may influence how users behave in VR. Lu et al. (2023) conducted a study where they compared a narrative and non-narrative design, with a comparison across active and passive VR experiences. The narrative condition was created by adding a background story before the VR activity. In the Active-VR condition, the participants who received the narrative spent a greater proportion of gameplay time engaged in moderate-to-vigorous physical activity and a lower proportion of time inactive than participants in the non-narrative condition. These results suggest that a narrative context can influence user behavior within VR. A limitation is that Lu et al. (2023) did not investigate Impossible Spaces in that regard and did not provide any direct measures for detecting spatial inconsistencies. The narrative was also delivered differently from the auditory narration used in the present study of this thesis.

Yang and Zhang (2022) investigated immersive storytelling across VR, 360° video, and conventional 2D. They included presence and flow as central variables and showed that presence was higher in the immersive conditions and was positively related to flow and enjoyment. However, the study varied the presentation medium rather than the presence or absence of a narrative.

Taken together, the reviewed work identifies attention guidance, user agency, engagement, and presence as relevant aspects of VR storytelling. However, the presented storytelling studies do not examine the detection of Impossible Spaces in a narrative context. The following section considers work that directly combines narrative design and Impossible Spaces.

2.6. Narrative Context and Impossible Spaces

A study by Fisher et al. (2017) directly combines Impossible Spaces, natural locomotion, and narrative design. They presented the idea of "intentional" Impossible Spaces, where the architectural manipulation is designed with a specific narrative intent. The spatial structure is not treated separately from the story world, as the setting and environmental events are used to make the spatial manipulation more believable. The approach is intended to increase the believability of the virtual environment, support dramatic agency, and facilitate a more natural integration of the locomotion technique into the experience. They conducted a case study with a VR thriller in a cave environment, where the cave structure was used to naturally hide the lines of sight. The implementation used room overlaps of up to approximately 50%. The study was conducted with three participants. All were able to identify the approximate direction of the landmark. They did not report feeling lost or noticing unnatural spatial behavior during the experience, but one experienced participant identified the manipulation afterwards (Fisher et al., 2017). It is important to note that the study had no non-storytelling comparison and an extremely small sample of participants. The narrative design and Impossible-Space design varied together, so it is impossible to isolate the effect of storytelling itself (Fisher et al., 2017). Nevertheless, this study provides an exploratory design precedent for integrating narrative context with Impossible Spaces.

A recent study developed a narrative VR museum about human space exploration, where users progress through historical periods. In this example, Impossible Spaces were used to fit the larger experience into a 2.5 m × 2.5 m physical area (Ferreira et al., 2025). They presented the participants with rooms functioning as stages of a chronological story progression (a sequence of the Medieval Era, Modern Era, and Future Era). Artifacts and environmental content provided the narrative information. The overlapping rooms were connected using portals and corridors to maintain natural walking. 24 participants were assessed regarding presence, cybersickness, spatial awareness, and the overall user experience. The participants generally evaluated the experience positively in terms of immersion and the overall experience, and approximately 60% were able to follow the narrative progression. The authors reported no evidence that the Impossible Space design prevented understanding of the chronological narrative (Ferreira et al., 2025). An important limitation is that this study did not provide any comparison with an otherwise identical non-narrative version. This study still shows the compatibility of natural walking, Impossible Spaces, and storytelling, but it did not determine whether a narrative context itself changes spatial detection.

These studies demonstrate that a narrative experience and Impossible Spaces can be combined. However, neither study has isolated the narrative context as an independent variable. Therefore, it remains unclear if the same VE with overlapping rooms is perceived differently when embedded in a narrative.

2.7. Research Gap

Previous work has highlighted the advantages of physical walking for spatial orientation and natural interaction in VR. Natural walking is limited by the physical tracking space (Jerald, 2015, Nilsson et al., 2018, Suma et al., 2012). Impossible Spaces were presented as a solution to fit larger virtual environments inside smaller physical areas with self-overlapping architecture. A substantial overlap is possible without the reliable detection of the overlap (Suma et al., 2012). However, detection does not depend on the overlap alone. The detection and overall spatial perception have been investigated in relation to overlap percentage, room configuration, path complexity, corridor geometry, endpoint positions, and transition design (Suma et al., 2012, Vasylevska and Kaufmann, 2015, Vasylevska and Kaufmann, 2017, Vasylevska et al., 2013, Rebelo et al., 2025). C.-B. Ciumedean et al. (2020) showed that another important factor is attention, which can considerably reduce the ability to detect overlapping architecture. The authors considered increased attentional demand and cognitive load as plausible explanations for the reduced detection rate. They also identified changes in urgency, suspense, affective state, and exposure time as possible alternative or additional explanations (C.-B. Ciumedean et al., 2020).

VR storytelling can be experienced spatially with the whole body rather than being observed only. The user takes an active role, and the narrative design can guide their attention. A VE itself can communicate a story, and a narrative context has been shown to influence the users behavior in some VR settings. Other work emphasizes the roles of attention, agency, and presence in VR storytelling (Arcagni and D'Aloia, 2021, Kazlauskaitė, 2025, Jang et al., 2023, Lu et al., 2023). Fisher et al. (2017) provided a direct combination of both research areas by integrating Impossible Spaces into a narrative VR experience. However, the study included only three participants. Additionally, Ferreira et al. (2025) have shown an implementation and evaluation of a larger narrative application using Impossible Spaces, but it provides no comparison between story and non-story conditions. C.-B. Ciumedean et al. (2020) have investigated attention and distractors in a narrative prison-escape scenario but did not isolate the effect of narrative context itself. Furthermore, Lu et al. (2023) compared narrative and non-narrative conditions in VR games but did not investigate spatial perception or Impossible Spaces.

Taken together, these studies leave open the question of whether the narrative context itself influences the perception and detection of Impossible Spaces. The present thesis addresses this gap through a controlled study manipulating the narrative context while keeping the spatial layout and tasks constant. This study will compare a storytelling and a non-storytelling version of the same Impossible Space experience. The narrative framing will be provided in the form of audio. It will be examined whether storytelling affects the awareness or detection of spatial inconsistencies, the perceived spatial coherence, disturbances caused by noticed

inconsistencies, and presence. Furthermore, attention, cognitive load, and urgency will be investigated.

The reviewed literature provides different theoretical motivations for the three hypotheses. Presence is connected to immersive narrative experiences, which suggests that a coherent narrative context may strengthen the user's sense of being within the VE (Yang and Zhang, 2022, Arcagni and D'Aloia, 2021). Previous work on Impossible Spaces shows that attentional distractors can reduce the noticeability of overlapping architecture, while VR storytelling involves mechanisms for guiding attention and may, therefore, influence how attention is distributed during an experience (C.-B. Ciumedean et al., 2020, Arcagni and D'Aloia, 2021). Suma et al. (2012) observed that even clearly noticeable Impossible Spaces did not necessarily lead to strongly negative reactions, while Fisher et al. (2017) proposed narrative integration as a way to support the believability of Impossible Spaces. This motivates examining whether spatial inconsistencies that are noticed are perceived as less disturbing when embedded in a narrative audio context.

These considerations motivated the research questions stated in Section 1.3 and formed the hypotheses below.

H1: Participants in the storytelling condition will report a higher level of presence than participants in the non-storytelling condition.

H2: Participants in the storytelling condition will be less likely to notice spatial inconsistencies than participants in the non-storytelling condition.

H3: Spatial inconsistencies that are noticed will be perceived as less disturbing in the storytelling condition than in the non-storytelling condition.

3. Design and Implementation of the VR Application

This chapter describes the design and implementation of the VR application that was developed for the user study. It first presents the main design requirements, followed by the spatial layout, tasks and interactions, and the two experimental conditions. Then, the technical implementation of the environment is described.

3.1. Design Goals and Requirements

The application was specifically designed to investigate the influence of storytelling on spatial perception. For both tested conditions, the same application was used with only one intended difference between the conditions. The two versions have an identical spatial layout, identical tasks and interactions, identical task-relevant information, the same number of audio clips with very similar durations (complete durations of 188 s and 195 s), as well as the same trigger points for the audio clips. The audio durations are approximately the same for both conditions to avoid differences between the conditions being attributed to this variable. The only experimental manipulation between the two VR experiences is the narrative or the absence of a narrative.

The tasks were chosen to be simple to avoid an unnecessarily high cognitive load while providing sufficient interaction to integrate the participants naturally into the environment. None of the tasks explicitly require the analysis of the spatial layout. Because this thesis focuses on spatial perception within a fixed real-world space, natural walking was used as the locomotion technique. This fits best for experiencing the room layout, distances, and the overlaps of the rooms. There was no direct attention drawn to Impossible Spaces before or during the experience.

Additionally, the use of horror, pursuit, time pressure, and any other stressful aspects was avoided to prevent unnecessary stress for the participants. The use of strong visual distractions was also avoided to reduce potential disruptive factors, allowing for the interpretation of possible differences between the two groups.

3.2. Virtual Environment and Spatial Layout

The VR environment consists of three sequential rooms: A, B, and C. The rooms are connected through two separate L-corridors. The whole walking sequence is as follows: Room A → Corridor 1 → Room B → Corridor 2 → Room C.

The three rooms have identical sizes of 2 m × 2.8 m each. The corridors have a size of 0.8 m × 4.2 m for the first part and 0.8 m × 2 m for the second part. The available real-world space is about 4 m × 4.5 m, of which 3.6 m × 4.2 m was used for the virtual environment.

There is a 50% overlap between rooms A and B, as well as between rooms B and C. Overlap means that one room shares approximately 50% of the same area as the adjacent room. Suma et al. (2012) reported a detection threshold of approximately 56% in a fixed-room condition, while Vasylevska and Kaufmann (2017) used a fixed overlap of 50% for investigating the influence of path and layout characteristics. Therefore, 50% was selected as a suitable overlap for this study.

The connecting corridors also partially occupy the same physical area as the rooms. The stated 50% overlap refers specifically to the shared area between the rooms and does not include the corridor–room overlaps. The corridors serve as transitions between the rooms, with one directional change in the form of a 90-degree turn per corridor. The 90-degree turns and opaque corridor walls ensure that participants have no direct line of sight between the rooms during the transitions. There are no windows or other visual connections between the rooms. Figure 3.1 shows the complete layout and the spatial overlap between the rooms. Both layouts shown in the figure occupy the same physical area.

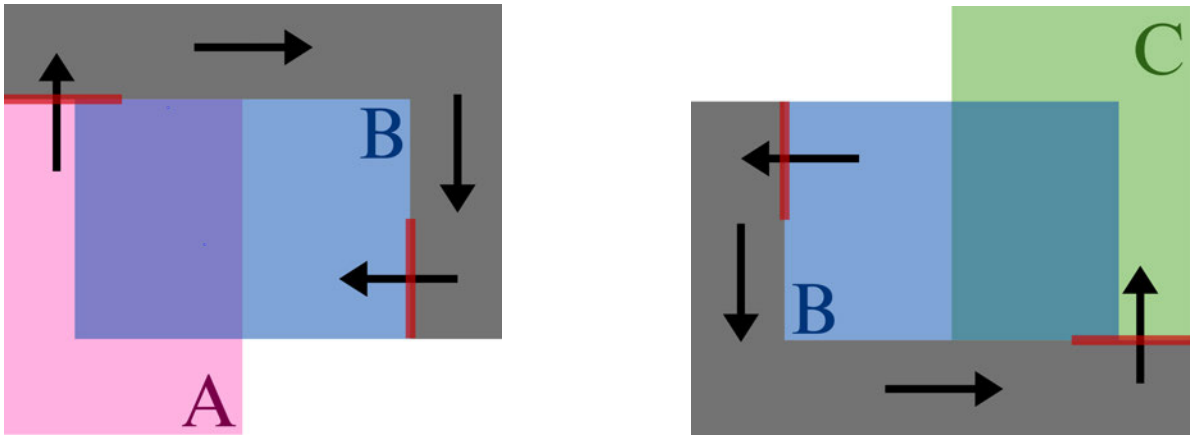

Figure 3.1.: Top-down views of the virtual environment: Rooms A–B (left) and Rooms B–C (right), showing the connecting corridor, the walking sequence, and the overlapping room areas.

The rooms are visually distinguishable, with objects and furniture inside each room mainly supporting the tasks and orientation. These differences support orientation and the individual task context without explicitly drawing attention to the spatial relationship between the rooms. Figure 3.2 shows the inside of the three rooms.

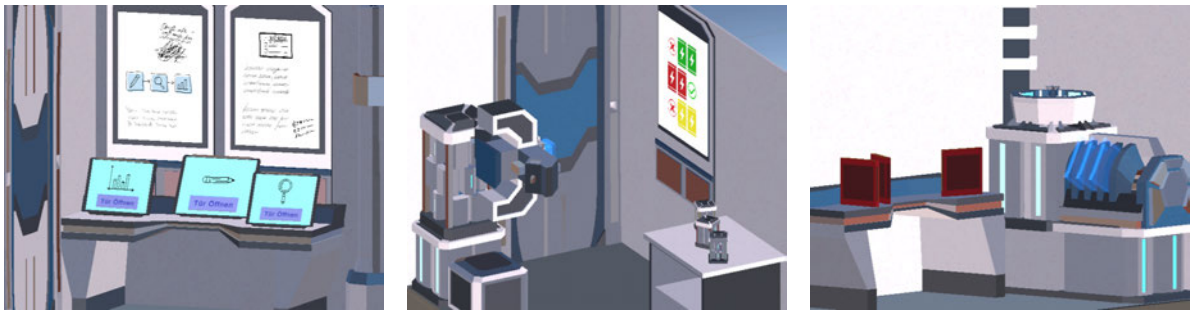

Figure 3.2.: Representative views of rooms in the VR environment (left to right): Room A, Room B, Room C.

3.3. Tasks and Interactions

The tasks that were presented to the participants provide a natural reason to remain in and interact with each room. For each room, there is one specific task, and successful task completion is required to unlock the next door. The tasks do not require hidden-object searches, extensive exploration, complex calculations, or complicated puzzles. They were designed to have a low difficulty and a short completion time to avoid unnecessarily high task-related cognitive demand.

The task in Room A has a computer control panel as the main interaction. Participants were required to press three buttons in the correct order using a visual hint displayed on the wall. After successful input, the door to the next area opens.

In Room B, the task is to choose one of three batteries for insertion into an emergency power device. For this task, the user is also presented with hints on the wall of the room. An incorrect battery produces a red light and an audio feedback signal. If the correct battery is inserted, the light is green, and the next door opens.

For the task in Room C, the participants needed to insert three cards into the designated slots of a device. After the completion of the third task, a clear ending of the VR experience is provided via audio. The tasks were designed to have simple interactions to maintain active participation but not to further distract the participants.

3.4. Experimental Conditions

The experimental manipulation consisted of the narrative framing of the audio information. The spatial environment, tasks, interactions, task-relevant information, voice, audio trigger locations, and number of audio clips were kept the same between both conditions.

The number of audio clips and the text-to-speech (TTS) voice are also the same in both conditions. The duration of the audio clips is similar in length to avoid the duration of the audio or the amount of perceived information via audio becoming a factor when evaluating the results further on. The synthesized voice was selected to have a relatively neutral character. It was intended to sound sufficiently natural for the storytelling condition while remaining neutral enough for the functional non-storytelling instructions, so that differences in voice characteristics would not become an additional factor between the conditions. Audio narration was selected because it allows narrative information to be presented without requiring participants to continuously focus on a specific visual element.

All audio scripts were produced in German, as they were presented to german speaking participants during the study. The six audio clips contain the same total number of words in both conditions (452 words). The total audio duration is 188 s in the storytelling condition and 195 s in the non-storytelling condition. The complete audio scripts for both experimental conditions are provided in Appendix A.

During the experience, there is no mention of distorted space, spatial anomalies, or Impossible Spaces in general. There is also nothing deliberately directing attention towards the spatial geometry, and there is no extreme threat or excessive urgency to complete the tasks and reach the end.

3.4.1. Storytelling Condition A

The storytelling condition is a science-fiction scenario set in a research facility. The story discusses an incident that took place before the participants' arrival, which led to the evacuation of the facility. The systems were separated and deactivated for safety reasons, and the participant is asked to help with the gradual reactivation and stabilization of the facility. "Dr. Amanda Voss" is the main character who communicates with the participant in the form of generated audio messages. With this character, a narrative is provided to explain previous events, the motivation for the current events, and a causal connection between the tasks. The participant takes an active role in the situation. The narrative follows a simple progression from an introduction to the reactivation of the facility systems, the restoration of the emergency power, the securing of research data, and a final resolution. In the beginning, the participants are given an introduction to the facility and situation by "Dr. Amanda Voss".

In Room A, they are asked to reactivate the system. In Room B, they are asked to restore the emergency power, and in Room C, they are asked to secure the research data. In the end, the participants are told that the stabilization of the facility was successful. All these steps are embedded in a narrative context. In the connecting corridors, there is additional information about the story and the progression to the next room.

3.4.2. Non-Storytelling Condition B

The non-storytelling condition consists of the same rooms, corridors, layout, and overlaps, as well as the same tasks and interaction possibilities. The non-storytelling audio distinguishes itself through functional and present-oriented wording. There is no named character, and no backstory is provided. There is no explanation of a previous incident or any narrative progression between the rooms. No deliberate emotional or narrative framing was added. With all this in mind, the goal was to allow the differences to be attributed as closely as possible to the narrative context.

3.5. Technical Implementation

The VR experience was developed with Unity version 6000.3.21f1 and the Meta XR SDK.[1] A Meta Quest 3S was used to present the experience to the participants. The complete hardware and physical study setup is described in Chapter4. Participants navigated the environment using natural walking. Before each study run, the experimental condition was selected through a start menu. The experimenter selected either Condition A (storytelling) or Condition B (non-storytelling). The application did not automatically reset after a completed run. Instead, it was closed and restarted for each participant before the corresponding condition was selected. The experience consists of multiple rooms within the same physical area, which are activated or deactivated after passing specific trigger points in the corridors. The switching of the activation and deactivation only happens when the previous room is visually occluded. The transitions are designed to remain visually unnoticed. The interactions that the participants encounter are pokeable buttons and holdable objects in the form of batteries and cards, as well as the insertion of those objects into designated places. The audio clips were played in each room. In Room C, two audio clips were played: one when entering the room and one when completing the last task. Additional audio clips were presented in the connecting corridors. These clips provide further narrative or functional information. The audio playback was controlled by trigger zones positioned at the beginning of each room and corridor. When a participant entered an audio trigger, the corresponding clip

[1]Unity Technologies. (2026). Unity(Version 6000.3.21f1) [Game development platform]. https://unity.com

started automatically. Each clip was played only once during a run and was not looped. The trigger positions were identical for the storytelling and non-storytelling conditions. The door control of rooms A and B depends on task and audio completion, while the door control of the corridors depends only on audio completion.

3.5.1. Assets and Audio Production

The visual task hints used in Rooms A and B were created specifically for the application using Canva.[2] Several environmental prefabs were taken from the *Sci-Fi Styled Modular Pack* asset pack by karboosx, obtained through the Unity Asset Store.[3] All spoken audio was generated using text-to-speech synthesis with ElevenLabs.[4] The same relatively neutral synthesized voice was used for both experimental conditions to prevent differences in speaker characteristics or vocal style from influencing the comparison. The door-opening sound effect was obtained from Freesound.org.[5]

3.5.2. Data Logging

During each run, the application automatically recorded timestamps at the audio triggers, as well as at the start and end of the experience. These timestamps were used to determine the duration of the complete VR experience and the time spent in the individual rooms and corridors. The log files were stored locally on the Meta Quest 3S during the study and were transferred to a computer afterward for further processing and analysis.

[2] https://www.canva.com/
[3] https://assetstore.unity.com/packages/3d/environments/sci-fi/sci-fi-styled-modular-pack-82913
[4] https://elevenlabs.io/
[5] "SFX Door Open.wav" by Paul368, licensed under Creative Commons 0: https://freesound.org/people/Paul368/sounds/264061/

4. Methodology

This chapter describes the methodology of the user study that was used to evaluate the influence of storytelling on the perception of Impossible Spaces. It presents the study design, participants, experimental setup, procedure, measures, and statistical analysis.

4.1. Study Design

A controlled user study with a between-subjects design was conducted. Two independent groups were tested. Group A was presented with the storytelling condition, and group B with the non-storytelling condition. Each participant experienced only one of these conditions to prevent a direct comparison of both versions by the same participant. The assignment of the condition alternated between A and B for each participant. Starting with the assignment of participant 1 to group A.

Between the two conditions, the intended experimental manipulation was the narrative framing. The spatial layout and tasks across the groups remained the same. The main focus was to investigate whether storytelling influences the perception of spatial inconsistencies in the virtual environment.

The main outcome variables were the detection of spatial inconsistencies, the perceived disturbance caused by detected inconsistencies, and presence. Spatial plausibility, task load, audio perception, spatial experience, and simulator sickness were included as additional measures to support the interpretation of possible differences between the two conditions.

4.2. Participants

20 participants took part in the study, with 10 participants in each group. The participants' ages ranged from 21 to 36 years ($M = 28.05$, $SD = 3.28$). 8 of the participants were female, and 12 were male. 85% reported at least some previous VR experience. As for gaming experience, 5 out of the 20 participants stated they never play 3D games, while 11 stated that they play such games 1 to 3 times a week or even more often. No prior experience with

VR or knowledge of Impossible Spaces was required. Participants were recruited through university communication channels and personal contacts. They were not given any prior information about the study topic or the study overall, except for the necessary instructions. All participants were informed that they could stop the study at any time without giving a reason.

4.3. Experimental Setup

The study was conducted in a controlled indoor environment with an unobstructed walking area of about 4 m × 4.5 m, with approximately 3.6 m × 4.2 m used by the environment. The available physical space was large enough to allow the participants to move through the virtual environment using natural walking without the need for artificial locomotion. The Head-Mounted Display(HMD) used was the Meta Quest 3S with the corresponding controllers for basic interactions. The audio was presented through the integrated speakers of the HMD. The experimenter remained nearby during the VR experience in case technical problems occurred, but did not assist participants with the tasks unless necessary. Before and after the VR experience, the participants completed the questionnaire on a laptop using Google Forms.[1] The same hardware and physical setup were used for both experimental conditions.

4.4. Procedure

For each participant, an individual study session was carried out. The participants were welcomed, and a brief explanation of the general procedure was given. The participants did not receive any information about the spatial manipulation or any other specifics regarding the study or thesis topic. They were informed about possible VR discomfort and their right to stop at any time.

Before the VR experience, the experimenter assigned a participant ID and the experimental group. Then, the participants were asked to fill out the first part of the questionnaire, which included questions regarding their age, gender, VR experience, and experience with 3D games, as well as the Simulator Sickness Questionnaire (SSQ) before the VR exposure. They were then given a short explanation of the VR interactions and positioned at a predefined starting point.

The participants were then asked to put on the HMD and proceed with their independent progression through the experience. During the VR experience, timestamps were recorded automatically at predefined points in the environment. These timestamps were used to

[1] https://docs.google.com/forms/

determine the time spent in each room and corridor, as well as the overall duration of the VR experience. In addition, the total duration of each study session was recorded.

After the experience, participants filled out the second part of the questionnaire, beginning with the second SSQ immediately after the VR experience, followed by an open question about unusual or noteworthy observations and another open question about the assumed purpose of the study. This was followed by the IPQ, the Raw NASA-TLX (Task Load Index), and questions regarding narration, audio, and spatial perception. This was followed by direct questions about geometric possibility and overlap. Prior knowledge of Impossible Spaces was assessed afterwards. The open question about unusual observations was intentionally presented before any direct questions about spatial plausibility or room overlap in order to assess spontaneous detection without first drawing attention to the spatial manipulation. At the end of the questionnaire, they were given the opportunity to leave some final open comments and thoughts about the study. The questionnaire was followed by a short debriefing and explanation of the actual study topic. The approximate total duration of one session was around 21 minutes.

4.5. Measures

4.5.1. Background Information

In the first part of the questionnaire, the participants were asked about their age, gender, previous VR experience, and how frequently they play games involving navigation through 3D environments. These measures were used to describe the sample and as exploratory variables for the interpretation of possible differences between participants and conditions. The complete questionnaire can be found in Appendix B.

4.5.2. Simulator Sickness Questionnaire

The complete 16-item SSQ (Kennedy et al., 1993) was given before and after the VR experience. Each symptom was rated on a scale from 0 (*none*) to 3 (*severe*). According to the standard weighted scoring procedure, scores were calculated for Nausea, Oculomotor symptoms, Disorientation, and Total Severity. The pre- and post-exposure scores were used to examine the possible changes in simulator-sickness symptoms during the VR experience.

4.5.3. Igroup Presence Questionnaire

A complete Igroup Presence Questionnaire (IPQ) (Schubert et al., 2001) was also presented to the participants. The IPQ consists of 14 items that are measured on a 7-point Likert scale ranging from 0 to 6. The IPQ consists of one General Presence item (G1) and three subscales: Spatial Presence (SP), Involvement (INV), and Experienced Realism (REAL).

The scores were calculated according to the official IPQ scoring procedure. SP2, INV3, and REAL1 were reverse-scored before calculating the corresponding subscale means. The IPQ is used as the main measure for the evaluation H1.

4.5.4. NASA Raw-TLX

The NASA Raw-TLX (S. Hart, 2006; S. G. Hart & Staveland, 1988) is used to assess the perceived task load. The participants rate their tasks from low to high across six dimensions: Mental Demand (thinking, deciding, calculating), Physical Demand (amount and intensity of physical movement), Temporal Demand (time pressure and pace), Performance (success in accomplishing task goals), Effort (how hard one has to work mentally or physically), and Frustration Level (irritation, stress, or discouragement). The ratings are given from 0 to 100 using 5-point increments. The Raw-TLX score was calculated as the unweighted mean of the six dimensions, without applying pairwise weighting.

4.5.5. Study-Specific Measures

In addition to the standardized questionnaires, the participants were given study-specific questions, which were the same for both groups A and B. Most of the questions were answered on a 7-point Likert scale, along with some open-ended questions that could be answered in writing. They were used to assess how strongly participants perceived the narrative context, how much attention they paid to the audio and the spatial environment, and how coherent the room layout felt to them. More direct questions about the room layout and possible overlaps were asked later in the questionnaire so that the participants were not made aware of the spatial manipulation too early. At the end of the questionnaire, the participants were asked if noticing a spatial inconsistency had a negative impact on their experience and whether they had previous knowledge of Impossible Spaces.

The four narrative-context items (NAR1–NAR4) were designed to measure a common construct and were averaged to form a narrative-context composite for the manipulation check. Internal consistency of this composite was assessed using Cronbach's α. The remaining study-specific rating items were primarily analyzed separately rather than being combined

Table 4.1.: Overview of the study-specific measures.

Measure	Items	Response	Purpose
Narrative context	NAR1–NAR4	1–7	Manipulation check for perceived narrative context
Narrative interest	ENG1	1–7	Interest in the development of the presented situation
Audio perception	AUD1–AUD3	1–7	Attention, distraction, and comprehensibility of the spoken information
Task clarity	TASK1	1–7	Perceived comprehensibility of the tasks
Urgency	DRG1	1–7	Perceived urgency of the situation
Spatial experience	RAU1–RAU5	1–7	Coherence, naturalness, spatial understanding, disturbance, and spatial attention
Spatial detection	DET1–DET4	Categorical / ordinal	Perceived physical possibility, confidence, overlap detection, and detected transition
Disturbance	DET5	1–5	Disturbance caused by a noticed spatial inconsistency
Prior knowledge	–	Categorical	Previous knowledge of Impossible Spaces and prior experience with impossible spatial layouts

into a single scale. For H2, explicit detection was examined using the direct overlap question (DET3). A response of "Yes" was treated as detection, while "No" and "Unsure" were treated as no clear detection. The separate question concerning whether the room arrangement would be physically possible in the real world (DET1) was analyzed as an additional measure for spatial plausibility. The disturbance rating (DET5) was analyzed only for participants who had explicitly reported detecting a possible room overlap in DET3. Participants who did not report detection were therefore excluded from the H3 comparison. Responses to the initial open question about unusual or unexpected observations were additionally reviewed for the spontaneous detection of spatial inconsistencies. A response was interpreted as spontaneous detection only when it explicitly referred to a spatial impossibility or room overlap in the spatial layout. Table 4.1 provides an overview of the study-specific measures.

4.5.6. Behavioral Timing Measures

The application automatically recorded the duration of the complete VR experience and the elapsed time for each room and corridor. The overall duration of the complete study session was additionally recorded separately. The timing measures were treated as descriptive behavioral measures rather than primary outcome variables.

4.6. Data Analysis

The questionnaire responses were exported from Google Forms and prepared for statistical analysis. Standardized questionnaires were scored according to their respective scoring procedures. The IPQ subscales were calculated using the official item assignments and reverse scoring, while the General Presence item was analyzed separately. SSQ Nausea, Oculomotor, Disorientation, and Total Severity scores were calculated using the standard weighted scoring procedure. The Raw-TLX score was calculated as the unweighted mean of its six dimensions.

Differences in the composite between the storytelling and non-storytelling conditions were analyzed using Welch's independent-samples t-test, with Hedges' g reported as the effect size.

For H1, the IPQ General Presence item was compared between conditions using a Mann–Whitney U test because it represents a single ordinal rating. Rank-biserial correlation (r_{rb}) was reported as the corresponding effect size. The multi-item IPQ subscales Spatial Presence, Involvement, and Experienced Realism were evaluated using Welch's independent-samples t-tests, with Hedges' g as the effect-size measure.

For H2, explicit detection of the spatial overlap was treated as a categorical outcome. Responses of "Yes" to the direct overlap question were classified as detection. "No" and "Unsure" were treated as no clear detection. The detection frequencies between the conditions were compared using Fisher's exact test because of the small cell counts. The odds ratio (OR) was reported as the effect-size measure.

For H3, the disturbance ratings were analyzed only with the results of the participants who reported that they detected a possible room overlap. Because the disturbance measure consisted of a single ordinal rating, the storytelling and non-storytelling conditions were compared using a Mann–Whitney U test. Rank-biserial correlation (r_{rb}) was reported as the effect size.

Raw-TLX scores were compared between conditions using Welch's independent-samples t-test with Hedges' g. The SSQ pre- and post-exposure scores, as well as the change scores, were analyzed descriptively. The pre–post change in Disorientation across participants was additionally examined using a Wilcoxon signed-rank test. A Wilcoxon signed-rank test was used because the pre- and post-exposure measurements were obtained from the same participants, and the Disorientation scores showed a strongly skewed distribution with several zero values.

The study-specific measures that were not directly associated with the hypotheses were primarily summarized descriptively to avoid unnecessary comparisons. The responses to the initial open question were reviewed for spontaneous mentions of a spatial inconsistency before the spatial questions that were asked later were considered.

All tests were two-tailed with $\alpha = 0.05$. Descriptive statistics are reported as the mean and standard deviation (M, SD) for composite or approximately continuous measures, and as the median and interquartile range (Mdn, IQR) where appropriate for single ordinal measures.

5. Results

This chapter presents the results of the user study. First, the sample and questionnaire data are described, followed by the manipulation check and the analyses related to the three hypotheses. Then, the additional measures regarding attention, task load, spatial experience, simulator sickness, and prior experience are presented.

5.1. Sample and Data Overview

20 participants took part in the study. 10 participants were in Group A, the storytelling condition, and 10 participants were in Group B, the non-storytelling condition. The participants had a mean age of 28.05 years ($SD = 3.28$). The ages ranged from 21 to 36 years. In the storytelling condition, the mean age was 27.70 years ($SD = 3.71$), and in the non-storytelling condition, it was 28.40 years ($SD = 2.95$). Of the 20 participants, 8 were female, and 12 were male. The demographic characteristics, previous VR experience, and gaming experience are summarized in Table 5.1.

There were no missing values for the main questionnaire measures. Study-specific questionnaire items were scored on their respective 1–7 scales. The IPQ was evaluated using its General Presence item and the three subscales: Spatial Presence, Involvement, and Experienced Realism. The NASA Raw-TLX was calculated as the unweighted mean of its six dimensions. The SSQ scores were calculated separately for the pre- and post-exposure measurements. The change scores were obtained by subtracting the pre-exposure score from the post-exposure score.

5.2. Manipulation Check

The manipulation check was used to examine whether the participants in the storytelling condition perceived a stronger narrative context than the participants in the non-storytelling condition. The four narrative-context items NAR1-NAR4 showed high internal consistency (Cronbach's $\alpha = .90$) and were therefore combined into a mean narrative-context score.

Table 5.1.: Sample characteristics by experimental condition.

Characteristic	**Storytelling** ($n = 10$)	**Non-Storytelling** ($n = 10$)	**Total** ($N = 20$)
Age, *M* (*SD*)	27.70 (3.71)	28.40 (2.95)	28.05 (3.28)
Age range	21–32	26–36	21–36
Gender, n (%)			
Male	7 (70%)	5 (50%)	12 (60%)
Female	3 (30%)	5 (50%)	8 (40%)
Previous VR experience, n (%)			
No experience	1 (10%)	2 (20%)	3 (15%)
Little experience	4 (40%)	3 (30%)	7 (35%)
Some experience	4 (40%)	2 (20%)	6 (30%)
Much experience	0 (0%)	1 (10%)	1 (5%)
Very much experience	1 (10%)	2 (20%)	3 (15%)
Gaming frequency, n (%)			
Never	1 (10%)	4 (40%)	5 (25%)
Less than once per month	3 (30%)	0 (0%)	3 (15%)
1–3 times per month	1 (10%)	0 (0%)	1 (5%)
1–3 times per week	3 (30%)	5 (50%)	8 (40%)
4 or more times per week	2 (20%)	1 (10%)	3 (15%)

The participants in the storytelling condition showed a higher narrative-context score ($M = 6.10$, $SD = 0.59$) than the participants in the non-storytelling condition ($M = 5.20$, $SD = 1.71$). However, Welch's t-test showed that this difference was not statistically significant, $t(11.13) = 1.58$, $p = .143$, Hedges' $g = .67$. The individual narrative-context items followed the same general descriptive pattern, with higher mean ratings in the storytelling condition. The descriptive values for the individual items and the composite score are presented in Table 5.2.

The manipulation check showed a descriptive difference in the intended direction, but the difference between the conditions was not statistically significant.

Table 5.2.: Narrative manipulation-check ratings by condition.

Measure	**Storytelling** *M* (*SD*)	**Non-Storytelling** *M* (*SD*)
NAR1: Coherent story	6.20 (0.63)	4.80 (2.04)
NAR2: Clear narrative role	5.90 (0.74)	5.00 (2.00)
NAR3: Meaningful purpose of the tasks	6.20 (1.03)	5.40 (1.90)
NAR4: Connection between audio, tasks, and environment	6.10 (0.88)	5.60 (1.71)
Narrative-context composite	**6.10 (0.59)**	**5.20 (1.71)**

Ratings ranged from 1 to 7. The narrative-context composite represents the mean of NAR1–NAR4; Cronbach's $\alpha = .90$.

5.3. Main Hypothesis Results

5.3.1. Presence (H1)

H1 predicted that the participants in the storytelling condition would report a higher level of presence than the participants in the non-storytelling condition. For the IPQ General Presence item, participants in the storytelling condition reported a median score of 4.50 ($IQR = 3.25–5.00$), while participants in the non-storytelling condition reported a median score of 5.00 ($IQR = 5.00–5.00$). A Mann–Whitney U test did not show a statistically significant difference between the conditions, $U = 28.00$, $p = .074$, $r_{rb} = -.44$. The descriptive difference was opposite to the direction predicted by H1.

The three IPQ subscales also showed no statistically significant differences between the conditions. Spatial Presence was slightly lower in the storytelling condition ($M = 4.60$, $SD = 0.83$) than in the non-storytelling condition ($M = 4.88$, $SD = 0.79$), $t(17.96) = -0.77$, $p = .449$, $g = -.33$. Involvement was similar between the storytelling condition ($M = 3.80$, $SD = 1.22$) and the non-storytelling condition ($M = 3.90$, $SD = 0.83$), $t(15.84) = -0.21$, $p = .833$, $g = -.09$. Experienced Realism was also lower in the storytelling condition ($M = 1.93$, $SD = 0.58$) than in the non-storytelling condition ($M = 2.43$, $SD = 0.97$), but the difference was not statistically significant, $t(14.66) = -1.40$, $p = .183$, $g = -.60$. The results of the presence measures are summarized in Table 5.3. Overall, H1 was not supported.

Table 5.3.: Presence measures by experimental condition.

Presence measure	**Storytelling**	**Non-Storytelling**	p	**Effect size**
General Presence (G1)	4.50 (3.25–5.00)	5.00 (5.00–5.00)	.074	$r_{rb} = -.44$
Spatial Presence	4.60 (0.83)	4.88 (0.79)	.449	$g = -.33$
Involvement	3.80 (1.22)	3.90 (0.83)	.833	$g = -.09$
Experienced Realism	1.93 (0.58)	2.43 (0.97)	.183	$g = -.60$

G1 is reported as Mdn (IQR), while the IPQ subscales are reported as M (SD). g = Hedges' g; r_{rb} = rank-biserial correlation. G1 was analysed using a Mann–Whitney U test; the remaining subscales were analysed using Welch's t-tests.

5.3.2. Detection of Spatial Inconsistencies (H2)

H2 predicted that the participants in the storytelling condition would be less likely to notice spatial inconsistencies than the participants in the non-storytelling condition. The detection was primarily assessed by asking participants whether they had noticed or had the impression that two rooms could spatially overlap.

Five out of the ten participants in the storytelling condition (50%) and five out of the ten participants in the non-storytelling condition (50%) reported noticing a possible room overlap. Fisher's exact test showed no association between experimental condition and explicit overlap detection, $p = 1.000$, $OR = 1.00$.

A similar result was obtained when the participants were asked whether the room arrangement could physically exist in the real world. Six out of ten participants in each condition judged the layout as physically impossible. Fisher's exact test again showed no difference between conditions, $p = 1.000$.

Before the direct questions about spatial manipulation, the participants were asked an open-ended question about whether they had noticed anything unusual or unexpected during the VR experience. Only one response clearly described such a spatial inconsistency. Because the spontaneous detection was rare and the classification of open-ended responses required interpretation, this measure was treated descriptively and was not used as the primary test of H2.

The detection results are summarized in Table 5.4. The results provide no evidence that the storytelling condition reduced the likelihood of detecting the spatial manipulation. H2 was therefore not supported.

5.3.3. Perceived Disturbance (H3)

H3 predicted that spatial inconsistencies that were noticed would be perceived as less disturbing in the storytelling condition than in the non-storytelling condition. This analysis included only the participants who explicitly reported noticing a possible room overlap. Because of this, five participants from each condition were included.

Participants in the storytelling condition reported a median disturbance rating of 2 (IQR = 1–2), compared with a median of 1 (IQR = 1–4) in the non-storytelling condition. A Mann–Whitney U test showed no statistically significant difference between the conditions, U = 12.00, p = 1.000, r_{rb} = −.04. H3 was therefore not supported.

Table 5.4.: Detection and disturbance of spatial inconsistencies by condition.

Measure	**Storytelling**	**Non-Storytelling**	p	**Effect size**
Explicit overlap detection, *n* (%)	5/10 (50%)	5/10 (50%)	1.000	OR = 1.00
Layout judged physically impossible, *n* (%)	6/10 (60%)	6/10 (60%)	1.000	OR = 1.00
Disturbance among participants detecting overlap, *Mdn* (IQR)	2 (1–2)	1 (1–4)	1.000	r_{rb} = −.04

OR = odds ratio; IQR = interquartile range; r_{rb} = rank-biserial correlation. Disturbance included only participants reporting overlap detection (n = 5 per condition).

5.4. Additional Measures

In addition to the variables directly related to the hypotheses, additional measures were collected to examine task load, attention, urgency, spatial experience, simulator sickness, and prior experience. These measures were mainly used to provide additional context for the main results.

5.4.1. Attention, Audio, Task Load, and Urgency

The overall NASA Raw-TLX score was similar between the two conditions. Participants in the storytelling condition reported a mean task-load score of 20.50 ($SD = 9.35$), compared with 22.25 ($SD = 9.50$) in the non-storytelling condition. A Welch's t-test showed no statistically significant difference, $t(18.00) = -0.42$, $p = .683$, $g = -.18$.

Ratings concerning the audio and tasks also showed broadly similar patterns between the groups. Attention to the audio was rated at $M = 5.00$ ($SD = 1.89$) in the storytelling condition and $M = 4.70$ ($SD = 1.95$) in the non-storytelling condition. Perceived distraction by the audio was descriptively lower in the storytelling condition ($M = 2.90$, $SD = 1.97$) than in the non-storytelling condition ($M = 4.00$, $SD = 2.11$). Audio comprehensibility was rated at $M = 5.90$ ($SD = 1.20$) and $M = 5.50$ ($SD = 1.65$), respectively.

Task clarity was high in both conditions, with a mean of 6.30 ($SD = 1.06$) in the storytelling condition and 6.10 ($SD = 1.10$) in the non-storytelling condition. Perceived urgency was comparatively low and nearly identical between conditions, with $M = 2.50$ ($SD = 1.27$) in the storytelling condition and $M = 2.40$ ($SD = 1.58$) in the non-storytelling condition. The additional questionnaire measures are summarized in Table 5.6.

5.4.2. Experience Duration

The duration of the VR experience and the time spent in the individual areas were recorded as additional behavioral measures. The mean VR run time was 4.75 minutes ($SD = 1.04$) in the storytelling condition and 4.91 minutes ($SD = 0.68$) in the non-storytelling condition. The overall study duration was also similar between conditions, with a mean of 21.54 minutes ($SD = 2.91$) for the storytelling condition and 20.91 minutes ($SD = 1.64$) for the non-storytelling condition. The descriptive timing measures for the individual areas are presented in Table 5.5.

Table 5.5.: Descriptive timing measures by experimental condition.

Measure	**Storytelling** *M* (*SD*)	**Non-Storytelling** *M* (*SD*)
Room A	1.76 (0.84)	1.60 (0.55)
C1	0.38 (0.04)	0.35 (0.02)
Room B	0.96 (0.23)	0.88 (0.10)
C2	0.41 (0.05)	0.39 (0.01)
Room C	1.32 (0.24)	1.66 (0.32)
VR run time	4.75 (1.04)	4.91 (0.68)
Overall study time	21.54 (2.91)	20.91 (1.64)

Values are reported in minutes as M (SD), with n = 10 per condition.

5.4.3. Spatial Experience

The participants in both conditions generally rated the spatial experience positively. Perceived spatial coherence was rated at $M = 5.20$ ($SD = 1.62$) in the storytelling condition and $M = 5.70$ ($SD = 1.70$) in the non-storytelling condition. The naturalness of transitions between areas was rated at $M = 4.80$ ($SD = 1.32$) for storytelling and $M = 5.80$ ($SD = 1.14$) for the non-storytelling condition. Understanding of the spatial connections received mean ratings of 5.10 ($SD = 1.52$) in the storytelling condition and 5.80 ($SD = 1.55$) in the non-storytelling condition.

Ratings indicating that the participants were not disturbed by the spatial layout were high in both conditions, with $M = 6.70$ ($SD = 0.48$) in the storytelling condition and $M = 6.40$ ($SD = 1.26$) in the non-storytelling condition. The participants also reported consciously attending to the spatial layout, with mean scores of 5.20 ($SD = 1.87$) and 5.80 ($SD = 1.23$), respectively. These descriptive results are also included in Table 5.6.

5.4.4. Simulator Sickness

Simulator sickness was assessed before and after the VR experience. The Total SSQ score increased from 28.42 ($SD = 24.57$) to 38.52 ($SD = 34.28$) in the storytelling condition, corresponding to a mean change of 10.10 ($SD = 21.81$). In the non-storytelling condition, the Total SSQ score changed from 18.33 ($SD = 18.94$) to 19.07 ($SD = 20.52$), corresponding to a mean change of 0.75 ($SD = 5.23$). The difference in Total SSQ change scores between conditions was not statistically significant, $p = .231$.

Across all participants, the median SSQ Disorientation score increased from 0.00 ($IQR = 0.00–17.40$) before the VR experience to 13.92 ($IQR = 10.44–41.76$) afterward. A Wilcoxon

Table 5.6.: Descriptive results for additional questionnaire measures.

Measure	**Storytelling** *M* (*SD*)	**Non-Storytelling** *M* (*SD*)
NASA Raw-TLX	20.50 (9.35)	22.25 (9.50)
Engagement, audio, and task-related measures		
Interest / engagement (ENG1)	5.50 (1.51)	5.30 (1.83)
Attention to audio (AUD1)	5.00 (1.89)	4.70 (1.95)
Distraction by audio (AUD2)	2.90 (1.97)	4.00 (2.11)
Audio comprehensibility (AUD3)	5.90 (1.20)	5.50 (1.65)
Task clarity (TASK1)	6.30 (1.06)	6.10 (1.10)
Perceived urgency (DRG1)	2.50 (1.27)	2.40 (1.58)
Spatial-experience measures		
Spatial coherence (RAU1)	5.20 (1.62)	5.70 (1.70)
Natural transitions (RAU2)	4.80 (1.32)	5.80 (1.14)
Understanding of spatial connections (RAU3)	5.10 (1.52)	5.80 (1.55)
Not disturbed by the spatial layout (RAU4)	6.70 (0.48)	6.40 (1.26)
Conscious attention to spatial layout (RAU5)	5.20 (1.87)	5.80 (1.23)

Study-specific items were rated on 7-point scales. NASA Raw-TLX represents the unweighted mean of its six dimensions.

signed-rank test showed a statistically significant increase in Disorientation, $W = 5.00$, $p = .003$. However, the change in Disorientation did not differ significantly between the storytelling and non-storytelling conditions, $p = .090$.

5.4.5. Prior Experience

Prior knowledge and experience related to Impossible Spaces were also documented because familiarity with spatial manipulations could potentially affect detection. Five participants in the storytelling condition and three participants in the non-storytelling condition reported prior knowledge of the term Impossible Spaces. Prior experience with impossible or non-Euclidean layouts was reported by five participants in the storytelling condition and four participants in the non-storytelling condition.

The exploratory analysis found no statistically significant relationship between prior knowledge of the term Impossible Spaces and explicit overlap detection, Fisher's exact test $p = .650$. Prior experience with impossible layouts was also not significantly associated with explicit detection, $p = .370$. These analyses were considered supplemental because prior experience was not part of the main hypotheses.

6. Discussion

The aim of this study was to investigate whether narrative context affects how people perceive Impossible Spaces in VR. Overall, the results did not support the three hypotheses. The storytelling condition did not lead to higher presence. It did not reduce the detection of spatial inconsistencies, and it also did not significantly reduce the disturbance caused by noticed inconsistencies. The manipulation check showed higher narrative-context ratings in the storytelling condition, but the difference between conditions was not statistically significant. Therefore, these outcomes should be interpreted with consideration of the strength of the manipulation and the small sample size.

6.1. Storytelling and Presence

The general presence was descriptively lower in the storytelling condition than in the non-storytelling condition, but the difference was not statistically significant. The effect for general presence was moderate ($r_{rb} = -.44$), but in the opposite direction to H1. The other IPQ subscales also showed no statistically significant differences between the conditions. H1 was therefore not supported.

Yang and Zhang (2022) reported a higher presence in immersive media conditions and found positive relationships between presence, flow, and enjoyment. Arcagni and D'Aloia (2021) discusses how narrative design and audiovisual cues can be used to guide attention in VR. However, neither of these works implies that simply adding narration must lead to an increase in presence. The results of this study suggest that a narrative context alone may not be sufficient. A possible explanation for this result may be that the control condition, the non-narrative condition, may not have been perceived as fully non-narrative. Both groups had sequential tasks, audio guidance, goals, and progression through the rooms. These elements may already have created coherence and purpose, which could leave the narrative manipulation too weakly differentiated. The environment and task structure may have affected presence more than the narration.

6.2. Storytelling and Detection of Impossible Spaces

In the storytelling condition, 5 out of the 10 participants from group A noticed an overlap when asked about it, and 6 out of 10 judged the layout as impossible. In the non-storytelling condition, it was 5 out of 10 and 6 out of 10 participants from group B. Only one person spontaneously described the spatial inconsistency clearly.

The lack of a difference between the conditions suggests that narrative context may not influence spatial detection in the same way as a clearly defined attentional distractor. While C.-B. Ciumedean et al. (2020) showed that an additional demanding task can reduce the detection of overlapping spaces, the storytelling manipulation in this study may not have drawn enough attention away from spatial processing to generate the same effect.

Another possible explanation is that the detection of Impossible Spaces may not necessarily depend on whether the provided audio is narrative or non-narrative but rather on the information itself. Both conditions included audio, tasks, and task-related visual information that required the attention of the participants. These elements may have influenced how much attention was left for the spatial layout, regardless of the narrative content of the audio. This study did not include a condition without providing the audio information. Therefore, this assumption cannot be evaluated directly from the current results.

The results of the Raw-TLX were almost the same across both conditions. The perceived urgency was also almost identical, as was the attention to the audio. The task clarity was high in both conditions. The distraction was descriptively higher in the non-storytelling group. These additional measures offer little evidence that the storytelling condition led to substantially greater cognitive demand or distraction. This may help explain why H2 was not supported.

Interestingly, while the spontaneous detection was rare, more participants reported the inconsistency when directly asked about the spatial layout. This suggests that the spatial inconsistency was often not noticeable enough to be reported unprompted, even though participants could identify it once their attention was directed toward the spatial layout. Regarding the prior experience of the participants, there was no significant association with detection.

6.3. Perceived Disturbance of Impossible Spaces

Disturbance ratings were generally low in both conditions, with a median of 2 (IQR = 1–2) in the storytelling condition and 1 (IQR = 1–4) in the non-storytelling condition. The difference between conditions was not statistically significant, and the effect size was very small. H3

was therefore not supported. Disturbance was low in both conditions. Both groups tolerated the spatial inconsistencies well. This is consistent with the observation of Suma et al. (2012) that noticeable Impossible Spaces did not necessarily produce strongly negative reactions. Fisher et al. (2017) also proposed that narrative integration can support believability, but the present results provide no clear evidence of an additional benefit of narrative framing. This pattern was also reflected in the overall spatial-experience ratings, where participants in both conditions reported that the spatial layout did not strongly disturb them. Overall, the Impossible Space appeared to be well tolerated in both conditions.

6.4. Interpretation of the Narrative Manipulation

A central issue when interpreting the results is the limited separation between the two experimental conditions. Although the participants in the storytelling condition rated the narrative context higher, the difference was not statistically significant. However, the effect size was moderate ($g = .67$). This indicates a noticeable difference between the conditions despite the uncertainty associated with the small sample. The non-storytelling condition also received relatively high ratings. This suggests that the non-storytelling condition may also have been perceived as partly narrative. This reduced the difference between conditions and may have made it harder to identify effects that were specifically due to the narrative context. Both groups received audio at the same locations and with a similar overall duration, while the narrative content differed between conditions. They had the same task progression, the same goals, and the same overall environment. It could be that the task order itself created a kind of story structure. The narrative differences between the audio versions may have been too subtle relative to the shared task structure and the amount of spoken information.

An additional factor may have been the decision to keep the audio duration similar between both conditions. This decision was made to prevent differences in the exposure time to the audio from becoming a factor. To keep the non-narrative instructions roughly at the same length as the narrative instructions, the functional information was spread across a longer audio segment without trying to add narrative context. This could have given the non-storytelling condition more structure and coherence than intended and could help explain the higher narrative-context ratings. Shortening the non-storytelling audio could have created a clearer distinction regarding the narration, but it would have also resulted in differences in audio duration and information exposure. If that had been the case, the differences between the conditions would not have been clearly attributed to storytelling alone. As a result, the study may have ended up comparing a stronger narrative to a weaker one, rather than a true narrative versus a non-narrative experience.

6.5. Limitations

With a total sample of 20 participants, the study had limited statistical power to detect small effects. This is very important to note for H3 because only 5 participants per condition remained for the evaluation. The limited separation between the storytelling and non-storytelling conditions also reduces the confidence that the study isolated the narrative context as intended. The study-specific questionnaire items were developed for this study and, unlike established questionnaires such as the IPQ and SSQ, have not been validated in previous independent studies. Their results should therefore be interpreted more cautiously than results obtained from established questionnaires. The explicit spatial questions may also have influenced participants and made them more attentive to the subject. Although the open-ended question that was asked beforehand allowed spontaneous detection to be assessed before the explicit questions were posed, the results regarding explicit detection remained dependent on direct questioning. Simulator sickness represents another potential limitation. Regarding the results from the SSQ, disorientation increased overall across both conditions. The change in disorientation did not significantly differ between the conditions, providing no clear evidence that it was specifically due to the narration. The increased disorientation may have affected the participants' attention or their experience of the environment. Because the experience consists of one story, one voice, one environment, and one type of Impossible Space, the results cannot be generalized to all storytelling experiences or all Impossible Space environments. The chosen between-subject design of the study provides the advantage of avoiding learning or comparison effects, but individual differences among the participants may contribute more strongly due to the small sample size. A potential floor effect should also be considered for H3. Disturbance ratings were already low in both conditions, which leaves limited room for the storytelling condition to further reduce perceived disturbance.

6.6. Implications and Future Work

Future studies should present a stronger contrast between the storytelling and non-storytelling conditions. Just shortening the non-storytelling instructions could create differences in audio duration and information exposure, which could make it difficult to determine whether a result was caused by the narrative content or the audio length. A pilot study could be used to pretest the manipulation and other factors before the full study. A larger sample size would provide a more precise estimate and greater statistical power to detect potential effects. A comparison of different narrative styles could also yield interesting results. A variation of the Impossible Space itself, with different overlap ratios, could also be interesting for future studies. Future studies could focus more on spontaneous detection measures that do not explicitly steer participants' attention toward spatial inconsistencies. A study with

participants who have or have not had prior experience with Impossible Spaces could also yield interesting results. A different but similar approach to this study would be to compare narrative audio, duration-matched functional audio, and minimal instructions or no audio at all. This would allow the effects of the narration to be separated more clearly from the effects of audio duration and guided information.

7. Conclusion

This thesis investigated whether a narrative context influences the perception of Impossible Spaces in VR, with a focus on presence, detection, and disturbance. A study with a between-subject design involving 20 participants was conducted. Two conditions, storytelling and non-storytelling, with the same spatial environment and the same tasks but different narrative framing, were compared.

The results did not yield clear evidence that narration changed the overall perception of the Impossible Space in this implementation. The evaluation yielded that storytelling did not increase presence, nor did it reduce detection. 50% of the participants in each condition explicitly reported noticing a possible overlap between rooms. The same number of participants in both conditions also described the spatial layout as physically impossible. Participants who noticed the spatial inconsistency did not report significantly different disturbance ratings between the conditions. Overall, the results did not support the three hypotheses.

The findings provide no clear evidence that the narrative framing alone changed the perception of Impossible Spaces in this study. The results also showed that the spontaneous detection of the spatial inconsistency was rare. Only one participant clearly described the spatial inconsistency before being directly questioned about the layout. This suggests that an Impossible Space can remain relatively undetected during a VR experience, even when participants are able to identify the inconsistency once their attention is explicitly directed toward it. Disturbance ratings were generally low, suggesting that detecting an Impossible Space did not necessarily result in a negative experience.

Something to take into account when interpreting the findings is the weak differentiation between the storytelling and non-storytelling conditions. The storytelling condition received higher narrative-context ratings, but the difference was not statistically significant. The non-storytelling condition was also rated as relatively narrative. Both conditions contained sequential tasks, goals, audio guidance, and progression through the environment. The duration of the audio was intentionally kept similar between both conditions to avoid the audio duration itself becoming a confounding factor. Because of that, the audio in the non-storytelling condition may still have created a perceived narration. This study may have compared stronger and weaker narrative framing rather than a completely narrative and a completely non-narrative experience.

The results must also be viewed in light of the limitations of the study. Because only 20 participants took part in the study, the analysis had limited statistical power. This was especially relevant for H3, since narrowing the dataset to those who detected the spatial inconsistency left only five participants in each condition. Also, the study only tested a single narrative, one virtual environment, and one implementation of an Impossible Space. Therefore, these results don't apply across every storytelling format or every Impossible Space design.

Even with these limitations, this study contributes to the understanding of how narrative framing can influence the perception of Impossible Spaces. Previous research has already investigated factors like spatial layout, path design, overlap, occlusion, and attentional demand. This study takes this direction one step further by testing whether narrative context itself changes presence, detection, or perceived disturbance. In the conditions tested in this study, no evidence for these predicted effects was found.

Future studies could investigate this relationship with a larger sample and a stronger separation between experimental conditions. Especially a comparison between narrative audio, duration-matched functional audio, and minimal instructions or no audio could help separate the effects of the narrative content from the effects of audio duration and guided information. Different narrative styles, overlap ratios, and types of spatial inconsistencies could also be examined.

In conclusion, storytelling did not significantly increase presence or reduce the detection or disturbance of Impossible Spaces in this study. The spatial inconsistencies were often not reported spontaneously and were generally not perceived as disturbing if they were detected. The results suggest that the perception of Impossible Spaces may depend on the interaction between narrative context, attention, task demands, and spatial design. More research is needed to better understand how these factors can be combined to create truly compelling virtual environments that go beyond the limits of physical space.

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Appendix A.

Audio Scripts

The following table contains the complete German audio scripts as presented to the participants. Both conditions contained six audio clips and a total of 452 words. The word count and audio duration are provided for each clip.

Table A.1.: Complete audio scripts used in the storytelling and non-storytelling conditions.

Segment	Condition	Audio Script
Room A	**Storytelling** *127 words, 52 s*	„Wenn du diese Nachricht hörst, befindest du dich im Kontrollbereich der Anlage. Ich bin Dr. Amanda Voss. Vor einigen Tagen kam es während eines Versuchs zu einem Unfall, und wir mussten die Forschungsanlage evakuieren. Dabei konnten wir unsere Arbeiten nicht abschließen und mehrere Systeme blieben deaktiviert. Damit unsere Forschung nicht verloren geht, müssen die wichtigsten Systeme Schritt für Schritt wieder aktiviert und stabilisiert werden. Einige Bereiche wurden während der Evakuierung voneinander getrennt, um weitere Schäden zu verhindern. Bitte hilf uns dabei, die Systeme wieder unter Kontrolle zu bringen und unsere Forschungsdaten zu sichern. Sobald das System dieses Raumes vollständig läuft, sollte sich die Tür automatisch öffnen. An meinem Computer findest du die Schaltflächen für den Neustart. Die Notizen im Raum zeigen dir, welche Schaltflächen du verwenden musst.“

Continued on next page

Table A.1 – *continued from previous page*

Segment	Condition	Audio Script
	Non-Storytelling *127 words, 55 s*	„Du befindest dich im Kontrollbereich der Anlage. In diesem Raum befindet sich ein Computersystem, über das der Bereich aktiviert werden kann. Mehrere Funktionen des Systems sind derzeit deaktiviert und müssen über die vorgesehenen Schaltflächen am Computer gestartet werden. Die benötigten Schaltflächen lassen sich anhand der Notizen im Raum bestimmen. Nutze dafür ausschließlich die Hinweise im Raum. Nutze die Hinweise in den Notizen, um die richtigen Schaltflächen auszuwählen, und aktiviere damit die erforderlichen Funktionen. Das System muss vollständig aktiviert sein, bevor die Tür zum nächsten Bereich freigegeben werden kann. Sobald alle erforderlichen Funktionen laufen, sollte sich die Tür automatisch öffnen. Warte, bis der Vorgang vollständig abgeschlossen und die Tür freigegeben wurde. Verlasse den Raum anschließend durch die geöffnete Tür und gehe in den anschließenden Korridor zum nächsten Bereich.“
Corridor 1	**Storytelling** *38 words, 17 s*	„Der Unfall begann im Energiebereich. Seit der Evakuierung arbeiten mehrere Abschnitte der Anlage getrennt voneinander. Im nächsten Raum befindet sich die Notstromversorgung, die wir benötigen, um das System weiter zu stabilisieren. Folge dem Korridor bis zum nächsten Bereich.“
	Non-Storytelling *39 words, 16 s*	„Dieser Korridor verbindet zwei getrennte Bereiche der Anlage. Im nächsten Raum befindet sich die Notstromversorgung, die für die weitere Stabilisierung des Systems benötigt wird. Folge dem Verlauf des Korridors bis zur nächsten Tür und betrete anschließend den nächsten Bereich.“
Room B	**Storytelling** *99 words, 37 s*	„Auf dem Tisch liegen drei Batterien für die Notstromversorgung. Während der Evakuierung habe ich die benötigte Batterie aus dem System genommen, weil wir nicht wussten, welche Geräte durch den Unfall beschädigt worden waren. Jetzt benötigen wir diese Batterie, um den nächsten Bereich wieder mit Strom zu versorgen. Welche der drei Batterien die richtige ist, kannst du anhand der Notizen im Raum erkennen. Prüfe dafür die Hinweise im Raum, wähle die passende Batterie aus und setze sie vollständig in das Gerät für die Notstromversorgung ein. Sobald das System die richtige Batterie erkannt hat, sollte sich die nächste Tür automatisch öffnen.“

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Table A.1 – *continued from previous page*

Segment	Condition	Audio Script
	Non-Storytelling *98 words, 39 s*	„Auf dem Tisch liegen drei Batterien für die Notstromversorgung. Das Gerät für die Notstromversorgung benötigt eine dieser Batterien, damit der nächste Bereich mit Strom versorgt und die Tür freigegeben werden kann. Welche der drei Batterien die richtige ist, lässt sich anhand der Notizen im Raum bestimmen. Prüfe die Hinweise und wähle die passende Batterie aus. Setze sie anschließend in das Gerät für die Notstromversorgung ein und warte, bis das System die Batterie erkannt hat. Sobald die Batterie eingesetzt und bestätigt wurde, sollte sich die nächste Tür automatisch öffnen. Die beiden anderen Batterien werden für diese Aufgabe nicht benötigt.“
Corridor 2	**Storytelling** *43 words, 20 s*	„Hinter diesem Korridor liegt die zentrale Sicherungsstation. Wir haben es vor der Evakuierung nicht mehr geschafft, die Sicherung dort abzuschließen. Dort können die verbliebenen Systeme stabilisiert und unsere Forschungsdaten gesichert werden. Dafür werden drei Sicherheitskarten benötigt. Folge dem Korridor bis zum letzten Bereich.“
	Non-Storytelling *43 words, 20 s*	„Dieser Korridor führt zur zentralen Sicherungsstation. Im nächsten Raum befinden sich drei Sicherheitskarten und das zugehörige Gerät. Alle drei Karten werden benötigt, um dort anschließend den Sicherungs- und Stabilisierungsvorgang zu starten. Folge dem Korridor bis zur nächsten Tür und betrete den letzten Bereich.“
Room C – Part 1	**Storytelling** *98 words, 43 s*	„Du hast die zentrale Sicherungsstation erreicht. Auf dem Tisch liegen die drei Sicherheitskarten. Alle drei werden benötigt, um die verbliebenen Systeme zu stabilisieren und die Forschungsdaten zu sichern. Während der Evakuierung blieb uns keine Zeit mehr, diesen letzten Schritt durchzuführen, deshalb läuft die Anlage seitdem nur in einem provisorischen Zustand. Setze die drei Karten nacheinander in das dafür vorgesehene Gerät ein und warte nach jeder Karte, bis sie erkannt wurde. Sobald alle drei Freigaben bestätigt sind, startet der Sicherungs- und Stabilisierungsvorgang automatisch. Dadurch sollen die Systeme wieder in einen stabilen Zustand versetzt und die Forschungsdaten vollständig gesichert werden.“

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Table A.1 – *continued from previous page*

Segment	Condition	Audio Script
	Non-Storytelling *98 words, 44 s*	„Du befindest dich an der zentralen Sicherungsstation. Auf dem Tisch liegen die drei Sicherheitskarten. Alle drei Karten werden benötigt, um den Sicherungs- und Stabilisierungsvorgang zu starten. Setze die Karten nacheinander in das dafür vorgesehene Gerät ein und warte nach jeder Karte, bis sie vom System erkannt wurde. Sobald alle drei Freigaben bestätigt sind, startet der Vorgang automatisch. Dabei werden die vorgesehenen Systeme stabilisiert und die Forschungsdaten gesichert. Warte, bis der Vorgang vollständig abgeschlossen ist. Die Aufgabe ist abgeschlossen, sobald alle drei Karten erkannt wurden und das System den erfolgreichen Sicherungs- und Stabilisierungsvorgang bestätigt. Weitere Eingaben sind nicht erforderlich.“
Room C – Part 2	**Storytelling** *47 words, 19 s*	„Es hat funktioniert! Die Systeme sind wieder stabil und unsere Forschungsdaten wurden erfolgreich gesichert. Damit können wir die Arbeit fortsetzen, die wir nach dem Unfall unterbrechen mussten. Du hast uns dabei geholfen, unsere bisherigen Forschungsergebnisse zu erhalten. Dafür sind wir dir sehr dankbar. Danke für deine Hilfe!“
	Non-Storytelling *47 words, 21 s*	„Der Vorgang wurde erfolgreich abgeschlossen. Die Systeme sind wieder stabil und die Forschungsdaten wurden vollständig gesichert. Alle drei Karten wurden erkannt und verarbeitet. Das System bestätigt nun den Abschluss. Damit ist die letzte Aufgabe beendet. Es sind keine weiteren Eingaben erforderlich. Der Durchgang ist damit vollständig abgeschlossen.“

Appendix B.

Questionnaire

The following table provides an overview of the questionnaire used in the study. The questionnaire was presented in German. The standardized measures included the Simulator Sickness Questionnaire (Kennedy et al., 1993), the Igroup Presence Questionnaire (Schubert et al., 2001), and the NASA Raw-TLX (S. Hart, 2006; S. G. Hart & Staveland, 1988). The remaining study-specific items were developed for the present study.

Table B.1.: Questionnaire items and response formats used in the study.

Section	Code	Item	Response format
Background Information			
Background	–	Alter	Numeric
Background	–	Geschlecht	Categorical
Background	–	Wie schätzt du deine bisherige Erfahrung mit Virtual Reality (VR) ein?	Keine Erfahrung – Sehr viel Erfahrung
Background	–	Wie häufig spielst du Videospiele auf PC, Konsole, Smartphone oder in VR, in denen du dich durch dreidimensionale Umgebungen bewegst?	Nie – 4 Mal pro Woche oder häufiger
Simulator Sickness Questionnaire (SSQ)			
The following 16 symptoms were assessed once before and once immediately after the VR experience. Response scale: 0 = gar nicht, 1 = leicht, 2 = mittel, 3 = stark.			
SSQ	–	Allgemeines Unwohlsein	0–3
SSQ	–	Müdigkeit	0–3
SSQ	–	Kopfschmerzen	0–3
SSQ	–	Überanstrengung der Augen	0–3
SSQ	–	Schwierigkeiten beim Fokussieren bzw. Scharfsehen	0–3

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Table B.1 – *continued from previous page*

Section	Code	Item	Response format
SSQ	–	Erhöhter Speichelfluss	0–3
SSQ	–	Schwitzen	0–3
SSQ	–	Übelkeit	0–3
SSQ	–	Konzentrationsschwierigkeiten	0–3
SSQ	–	Druckgefühl im Kopf	0–3
SSQ	–	Verschwommenes Sehen	0–3
SSQ	–	Schwindel bei geöffneten Augen	0–3
SSQ	–	Schwindel bei geschlossenen Augen	0–3
SSQ	–	Gleichgewichtsstörungen / Drehschwindel	0–3
SSQ	–	Magenbeschwerden (unangenehmes Gefühl im Magen, noch unterhalb von Übelkeit)	0–3
SSQ	–	Aufstoßen	0–3
Initial Open Questions			
Open question	OPEN1	Ist dir während der VR-Erfahrung etwas Besonderes, Ungewöhnliches oder Unerwartetes aufgefallen? Falls ja, beschreibe bitte kurz, was dir aufgefallen ist.	Open text
Open question	OPEN2	Was glaubst du, was in dieser Studie untersucht wurde?	Open text
Igroup Presence Questionnaire (IPQ)			
All IPQ items were answered on the official seven-point response scales ranging from 0 to 6.			
IPQ	G1	In der computererzeugten Welt hatte ich den Eindruck, dort gewesen zu sein...	7-point scale (0–6)
IPQ	SP1	Ich hatte das Gefühl, dass die virtuelle Umgebung hinter mir weitergeht.	7-point scale (0–6)
IPQ	SP2	Ich hatte das Gefühl, nur Bilder zu sehen.	7-point scale (0–6)
IPQ	SP3	Ich hatte nicht das Gefühl, in dem virtuellen Raum zu sein.	7-point scale (0–6)
IPQ	SP4	Ich hatte das Gefühl, in dem virtuellen Raum zu handeln statt etwas von außen zu bedienen.	7-point scale (0–6)
IPQ	SP5	Ich fühlte mich im virtuellen Raum anwesend.	7-point scale (0–6)

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Table B.1 – *continued from previous page*

Section	Code	Item	Response format
IPQ	INV1	Wie bewusst war dir die reale Welt, während du dich durch die virtuelle Welt bewegt hast (z.B. Geräusche, Raumtemperatur, andere Personen etc.)?	7-point scale (0–6)
IPQ	INV2	Meine reale Umgebung war mir nicht mehr bewusst.	7-point scale (0–6)
IPQ	INV3	Ich achtete noch auf die reale Umgebung.	7-point scale (0–6)
IPQ	INV4	Meine Aufmerksamkeit war von der virtuellen Welt völlig in Bann gezogen.	7-point scale (0–6)
IPQ	REAL1	Wie real erschien dir die virtuelle Umgebung?	7-point scale (0–6)
IPQ	REAL2	Wie sehr glich dein Erleben der virtuellen Umgebung dem Erleben einer realen Umgebung?	7-point scale (0–6)
IPQ	REAL3	Wie real erschien dir die virtuelle Welt?	7-point scale (0–6)
IPQ	REAL4	Die virtuelle Welt erschien mir wirklicher als die reale Welt.	7-point scale (0–6)
NASA Raw-TLX			
Raw-TLX	MD	Mentale Anforderung: Wie viel kognitives und wahrnehmungsbezogenes Denken, Entscheiden oder Suchen war nötig?	0–100
Raw-TLX	PD	Physische Anforderung: Wie viel körperliche Aktivität (z.B. Drücken, Ziehen, Steuern) war erforderlich?	0–100
Raw-TLX	TD	Zeitliche Anforderung: Welcher Zeitdruck entstand durch das Tempo der Aufgaben?	0–100
Raw-TLX	PERF	Leistung: Wie erfolgreich fühlte man sich bei der Zielerreichung?	0–100
Raw-TLX	EFF	Anstrengung: Wie hart musste man arbeiten, um das erbrachte Niveau zu erreichen?	0–100
Raw-TLX	FR	Frustration: Wie unsicher, entmutigt oder gestresst fühlte man sich dabei?	0–100
Audio and Narrative Measures			
Narrative context	NAR1	Die gesprochenen Informationen vermittelten mir eine zusammenhängende Geschichte.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu

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Table B.1 – *continued from previous page*

Section	Code	Item	Response format
Narrative context	NAR2	Ich hatte das Gefühl, innerhalb der dargestellten Situation eine bestimmte Rolle einzunehmen.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Narrative context	NAR3	Meine Handlungen hatten innerhalb der dargestellten Situation einen nachvollziehbaren Zweck.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Narrative context	NAR4	Die Audioaufnahmen verbanden die einzelnen Räume und Aufgaben zu einem zusammenhängenden Ablauf.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Narrative interest	ENG1	Ich war daran interessiert, wie sich die dargestellte Situation weiterentwickelt.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Audio perception	AUD1	Ich habe den gesprochenen Informationen aufmerksam zugehört.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Audio perception	AUD2	Die gesprochenen Informationen haben meine Aufmerksamkeit von der räumlichen Umgebung abgelenkt.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Audio perception	AUD3	Die gesprochenen Informationen waren für mich leicht verständlich.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Task clarity	TASK1	Die Aufgaben waren für mich leicht verständlich.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Urgency	DRG1	Die dargestellte Situation vermittelte mir ein Gefühl von Dringlichkeit.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Spatial Experience			

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Table B.1 – *continued from previous page*

Section	Code	Item	Response format
Spatial experience	RAU1	Die räumliche Anordnung der Umgebung wirkte für mich stimmig.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Spatial experience	RAU2	Die Übergänge zwischen den einzelnen Räumen wirkten für mich natürlich.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Spatial experience	RAU3	Ich hatte ein klares Verständnis davon, wie die einzelnen Räume räumlich miteinander verbunden waren.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Spatial experience	RAU4	Die räumliche Anordnung der Umgebung hat mich während der Erfahrung nicht gestört.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Spatial experience	RAU5	Ich habe während der Erfahrung bewusst auf die räumliche Anordnung der Räume und Korridore geachtet.	1 = stimme überhaupt nicht zu – 7 = stimme vollständig zu
Direct Spatial Questions			
Spatial detection	DET1	Glaubst du, dass die räumliche Anordnung der Räume so auch in der realen Welt möglich wäre?	Ja / Nein / Unsicher
Spatial detection	DET2	Wie sicher bist du dir bei der vorherigen Einschätzung?	1–7
Spatial detection	DET3	Ist dir während der Erfahrung aufgefallen oder hattest du den Eindruck, dass sich zwei Räume räumlich überschneiden könnten?	Ja / Nein / Unsicher
Spatial detection	DET4	Bei welchem Übergang ist dir eine mögliche räumliche Überschneidung aufgefallen?	Raum A–B / Raum B–C / beide / nicht zuordenbar / keine Überschneidung
Disturbance	DET5	Falls dir eine räumliche Besonderheit oder Unstimmigkeit aufgefallen ist: Wie stark hat diese dein Erlebnis gestört?	1 = überhaupt nicht – 5 = sehr stark / nicht zutreffend
Prior Knowledge and Final Questions			

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Table B.1 – *continued from previous page*

Section	Code	Item	Response format
Prior knowledge	–	Kanntest du den Begriff “Impossible Spaces” bereits vor dieser Studie?	Ja / Nein / Unsicher
Prior experience	–	Hast du bereits vor dieser Studie VR-Anwendungen oder Videospiele erlebt, in denen Räume oder Umgebungen räumlich unmöglich bzw. nicht mit einer normalen realen Raumaufteilung vereinbar waren?	Ja / Nein / Unsicher
Final question	–	Gab es etwas, das dich während der VR-Erfahrung besonders abgelenkt, verwirrt oder auf andere Weise beeinflusst hat?	Open text
Final question	–	Hast du weitere Anmerkungen zur VR-Erfahrung?	Open text

Appendix C.

Supplementary Results

C.1. Study-Specific Questionnaire Measures

Table C.1.: Descriptive statistics for the study-specific questionnaire measures by condition.

Measure	**Storytelling** *M* (*SD*)	**Non-Storytelling** *M* (*SD*)
NAR1	6.20 (0.63)	4.80 (2.04)
NAR2	5.90 (0.74)	5.00 (2.00)
NAR3	6.20 (1.03)	5.40 (1.90)
NAR4	6.10 (0.88)	5.60 (1.71)
ENG1	5.50 (1.51)	5.30 (1.83)
AUD1	5.00 (1.89)	4.70 (1.95)
AUD2	2.90 (1.97)	4.00 (2.11)
AUD3	5.90 (1.20)	5.50 (1.65)
TASK1	6.30 (1.06)	6.10 (1.10)
DRG1	2.50 (1.27)	2.40 (1.58)
RAU1	5.20 (1.62)	5.70 (1.70)
RAU2	4.80 (1.32)	5.80 (1.14)
RAU3	5.10 (1.52)	5.80 (1.55)
RAU4	6.70 (0.48)	6.40 (1.26)
RAU5	5.20 (1.87)	5.80 (1.23)

C.2. Simulator Sickness Questionnaire

Table C.2.: Descriptive SSQ results by experimental condition.

	Storytelling			Non-Storytelling		
Measure	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**
Total Severity	28.42 (24.57)	38.52 (34.28)	10.10 (21.81)	18.33 (18.94)	19.07 (20.52)	0.75 (5.23)
Disorientation	20.88 (25.63)	47.33 (41.08)	26.45 (26.61)	4.18 (9.40)	12.53 (13.84)	8.35 (9.73)

Values are reported as M (SD). Change scores were calculated as post-exposure minus pre-exposure scores.

C.3. Additional Spatial and Detection Measures

Table C.3.: Additional spatial, detection, and prior-experience results by condition.

Measure	**Storytelling**	**Non-Storytelling**
Explicit overlap detection (DET3), Yes	5/10 (50%)	5/10 (50%)
Layout judged physically impossible (DET1)	6/10 (60%)	6/10 (60%)
Disturbance among participants detecting overlap, *Mdn* (IQR)	2 (1–2)	1 (1–4)
Prior knowledge of the term Impossible Spaces	5/10 (50%)	3/10 (30%)
Prior experience with impossible spatial layouts	5/10 (50%)	4/10 (40%)

C.4. Behavioral Timing Measures

Table C.4.: Participant-level behavioral timing measures.

ID	**Condition**	**Room A**	**Corr. 1**	**Room B**	**Corr. 2**	**Room C**	**VR Time**	**Study Time**
001	Storytelling	1.22	0.37	1.12	0.40	1.33	3.22	19.55
002	Non-Storytelling	1.18	0.35	0.83	0.38	1.25	4.03	19.21
003	Storytelling	1.40	0.37	1.43	0.38	1.17	4.78	19.05
004	Non-Storytelling	1.82	0.35	0.88	0.38	1.78	5.25	20.43

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Table C.4 – *continued from previous page*

ID	Condition	Room A	Corr. 1	Room B	Corr. 2	Room C	VR Time	Study Time
005	Storytelling	1.58	0.37	0.83	0.38	1.55	4.75	19.48
006	Non-Storytelling	1.37	0.40	1.12	0.42	1.93	5.27	22.03
007	Storytelling	4.02	0.42	1.07	0.38	1.27	7.20	21.44
008	Non-Storytelling	1.35	0.37	0.78	0.40	1.32	4.23	21.36
009	Storytelling	1.40	0.37	0.72	0.40	1.25	4.17	19.35
010	Non-Storytelling	1.67	0.33	0.88	0.38	1.78	5.12	20.23
011	Storytelling	1.55	0.40	0.78	0.38	1.55	4.68	28.43
012	Non-Storytelling	1.57	0.35	0.85	0.40	1.55	4.75	23.51
013	Storytelling	1.30	0.35	1.17	0.37	0.77	4.00	22.40
014	Non-Storytelling	1.02	0.33	0.82	0.38	2.25	4.82	20.08
015	Storytelling	1.40	0.42	0.85	0.43	1.33	4.48	21.24
016	Non-Storytelling	1.73	0.35	0.90	0.38	1.85	5.25	19.56
017	Storytelling	2.22	0.33	0.90	0.38	1.55	5.42	20.30
018	Non-Storytelling	1.27	0.35	0.77	0.40	1.28	4.07	19.16
019	Storytelling	1.52	0.45	0.75	0.53	1.47	4.77	24.18
020	Non-Storytelling	3.00	0.33	0.93	0.40	1.55	6.27	23.52

Eigenständigkeitserklärung

Hiermit versichere ich, dass ich die vorliegende Bachelorarbeit mit dem Titel

Narration and Impossible Spaces: The Influence of Storytelling on Spatial Perception in Virtual Reality

selbstständig und nur mit den angegebenen Hilfsmitteln verfasst habe. Alle Passagen, die ich wörtlich aus der Literatur oder aus anderen Quellen wie z. B. Internetseiten übernommen habe, habe ich deutlich als Zitat mit Angabe der Quelle kenntlich gemacht.



Hamburg, 27. Oktober 2026