Portals in VR: Exploring Visual and Auditory Tools' Effects on Portal Design Fall 2024/2025

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Abstract

Many virtual reality (VR) experiences require transitioning between different environments or scenes in a way that maintains a cohesive narrative and a strong sense of presence. In this report, we investigate and evaluate an audio-visual portal transition technique, where users can both see and hear activity in the destination scene before stepping through the portal. We conducted a user study comparing four conditions: No portal audio or visual information (generic transition), Portal visuals only, Portal audio only, and Both audio and visuals enabled for portals. We have 6 participants, who each evaluated presence, continuity, and preference, as these factors are important to effective scene transitions in VR storytelling. The results show that adding audio- visual previews to portals significantly improved the previously mentioned factors compared to a generic portal without any preview, and of which audio scored the highest in every category.

1 Introduction

Teleportation as a concept has long captivated the human imagination as an instant and seamless method of travel, however, as of today, it remains unattainable in the physical world. Virtual Reality (VR), on the other hand, gives us a unique opportunity to simulate and explore such imaginative ideas and transform them into interactive experiences. This study aims to explore the use of portals as a travel technique within VR, evaluating its effectiveness and potential to enhance the user's experience and presence. In this project we explore how elements such as sound and visuals when added to the portal can affect the user's experience, and if they enchance the user's sense of presence in a virtual environment. We wanted to optimize portals for greater immersion and user satisfaction, and one way to do that is to draw users to the portals by giving them a sense of what lies behind it. In order to hint at where the portal leads, the user should either see where they're going to or hear a noise as these are the senses we can control in VR. The goal of this experiment is to test 4 different modes for the portals by testing how different visual and auditory designs affected the user's experience and presence in the VR environment. We aim to find which technique will make the portal teleportation the most engaing for the player and doesn't break presence or cause disruption.

2 Motivation

The reason portals are an attractive concept in VR is because they introduce an interactive travel method that enables the user to travel large distances instantaneously. Other travel methods, such as walking, may cause fatigue and disengagement to the player when they are required to travel large distances in the virtual environment. Free teleportation, though faster than walking, can introduce some disorientation as players must reorient themselves after each teleportation to a predefined space. Portals, on the other hand, can offer a faster and less disorienting alternative, given they're implemented effectively. Despite its advantages, portal-based teleportation can disorient the player and disrupt their presence by increasing the user's awareness of the simulation. This study was conducted to evaluate how variations of visual and audiory designs can enhance the satisfaction and immersiveness of portal-based teleportation, with the goal being maintaining a strong sense of presence and continuity for the player. Presence here is the player's feeling of being there within the virtual environment and experiencing it as if it is the real world, and continuity here refers to the uninturrupted feeling of being there without being aware of the real world or that they're in a simulation either.

3 Related work

Teleportation or portal teleportation in VR is not a new concept and multiple studies have explored its implementation in VR. Various approaches have been proposed to optimize portals for navigation, address challenges such as VR sickness, and enchance user experience. Additonally, research into continuity and multimodal sensory integration shows the importance of maintaining presence and immersion during scene transitions. The studies below provide a foundation for our investigation into how audio and visual cues can enchance portal-based teleportation in VR.

3.1 Portals as a Reorientation Technique

Freitag et al. (2014) [6] conducted a study with the aim to utilize interactive portals as a tool to reorient players and guide them back to a safe position, which itself is a variation of redirected walking [3], but just with using portals. This study addresses the issue of physical space limitation and how it prevents real walking from being continuously used. This issue with real walking techniques is usually fixed using reorientation techniques that leads the player away from their physical boundaries, and since these techniques interrupt or use rotational gain which leads to simulator sickness, they wanted to utilize portals as a reorientation technique and reduce VR sickness. In the simulation, when the player reaches a physical boundary, they are interrupted by a barrier tape and in order to continue walking, they are required to create a "target portal" to the desired location using raycasting selection and a pointing device and after doing so, a start portal will appear in a position that redirects the player to walk somewhere inside their physical boundary and

once the player steps through, they will arrive at their target location while having also been reoriented to somewhere inside their physical boundary. The point of this technique was to minimize simulator sickness and the results showed that none of the user experienced VR sickness.

3.2 Portals and Doorway Effect

In a research paper by Gemert et al. [8], the aim was to study a psychological phenomenon called the "doorway effect" that states that passing through a doorway or moving from a location to another results short-term memory loss. Utilizing VR here as a tool to further examine this phenomenon, two studies were conducted. One replicating the previous research on doorway effect but in VR using natural walking and teleportation, while the other explored the effect of five different doorway visualizations were used, no door, ordinary door, transparent sliding doorm opaque sliding door, and portal. Portals here are used a ascience fiction element as it doesn't show the next room, and instead a light flashes and the user is teleported to the other room once they walk through it. The results for this study revealed no significant differences in crossing different doorway visualization using walking or teleportation. However, it contributes to the understanding of this phenomenon by offering potential explanations for the findings and identifying limitations that future studies should address or explore further.

3.3 Portals and Transitional Environments

This study explores how replicating a user's surroundings in VR helps with their perception of distance. As in Steinicke et al. [7] they discuss how ego centreic distance appears compressed compared to the real world in immersive virtual environments. Building on prior research that demonstrates that replicating a person's environment improves distance perception, this study uses portals as a travel method. Portals here serve as a transitional interface between the virtual replica of the physical world and the virtual environment. The study here makes use fictional and magical qualities of portals, which are often perceived as connections or channels between two distant or separate worlds. To enhance the transition experiment, the study uses visual elements that allow the users to preview their destination environment by looking into the portal. The study found that the transitional environment helped the players improve their distance estimation skills as they were able to take that estimation from the transitional environment and into whatever environment they travel to, and these results were consistent regardless of the destination environment.

3.4 Of Portals and Orbs: An Evaluation of Scene Transition Techniques for Virtual Reality

This study conducted by Husung and Langbehn (2019) [4] explored six different transition techniques for scene switching in VR environments, with a focus on presence, continuity, usability and user preference. Their evaluation included three traditional techniques adapted from film (Cut, Fade and Dissolve), and three VR-specific techniques (Portal, Orb and Transformation). These techniques were rated for their ability to maintain the sense of "being there" in the virtual world, an important part of VR experiences. Through a user study involving 22 participants, the research found that Orb and Portal transitions, which leverage interactive features of VR such as real walking and object manipulation, achieved the highest ratings for presence and continuity. The findings suggest that interactive visually seamless transitions enchance user immersion and overall satisfaction, while aprupt transitions like Cut detracts from the experience. This study highlights the importance of designing scene transitions that align with the unique capabilities and requirements of a virtual environment.

3.5 Movie Editing and Cognitive Event Segmentation in Virtual Reality Video

Serrano et al. (2017) [1] explored how event segmentation theory applies to VR by analyzing continuity editing in 360°degree narrative videos. The study examined viewers' gaze behaviors and how spatial or temporal discontinuities across edit boundraies influenced their perception of continuity. They found that while action continuities strongly indicated event boundries, spatial and temporal continuity edits maintained a coherent narrative flow in immersive environments. The results suggest that cognitive mechanisms supporting event segmentation in traditional film also function in VR, giving guidelines for maintaining viewer attention and continuity in VR storytelling.

3.6 Enhancing Presence Through Sound in Virtual Environments

Larsson et al. (2000) [5] explored the impact of binaural sound rendering on user presence and performance in virtual environments. Two experiments compared unimodal (visual-only) and bimodal (visual and auditory) setups, as well as low- and high-quality auralization (simulation of how sound behaves in a space to create realistic and immersive auditory experiences). The results indicate that high-quality congruent auditory information (matching visual information) significantly enchanced presence, satisfaction and user focus. High-quality auditory cues also improved sound localization and overall realism. However, task performance showed only a little improvement, suggesting that congruence between auditory and visual stimuli may be more important for presence than task-related outcomes. This study shows the importance of multimodal integration for creating immersive virtual environments.

3.7 Connecting Related Work to Our Project

Papers such as Freitage et al., Gemert et al., and Steinicke et al. [6–8] have explored the use of portals to address different challenges in VR, including VR sickness, distance estimation, and even psychological phonemenon. Our paper focuses on utilizing portals as a travel by incorporating visual and auditory aids. Husung and Langbehn's study [4] shows that interactive transitions like portals enchance presence and continuity in VR. We build on this by trying evaluating how visual and auditory cues can optimize portals to further improve user immersion, becase as demonstrated by Larsson et al. [5], high-quality auditory cues enchance presence and realism. Our project then made use of audio previews in portals to complement visual cues and create a cohesive teleportation experience. The importance of spatial and temporal continuity in maintaining a narrative coherence is highled in the study by Serrano et al. [1]. We apply this by using the points, and designing the portals so that they provide sensory continuity and minimize disruptions to presence during transitions.

4 Technique

In order to test how different auditory and visual designs can enhance teleportation and make it more immersive, we started our implementation with a simple portal design with no audio-visual (window) effects. Once the user steps through, the player is teleported into another environment. That is done using a script that's added to the portal object and it checks if and when the player's collider comes in contact with the portal collider, they're then transferred to the other portal's environment. We then added different designs to the portals. In one design, the user can not see but can only hear the environment at a distance before reaching the portal. In another design, the user can not hear but can see through the portal, the environment they're traveling to. The last design was being able to both see and hear the environment they're about to travel to.

We wanted portals to mimic the audio of the environment participants was about to teleport to. To achieve this, we wrote a script, that can listen to all audios in the scene, uses a basic attenuation formula(inverse square law), to calculate the perceived loudness based on the distance from the script. This allows it to find the loudest audio near it, and attach it to the other portal's AudioSource. So when the player enters a certain radius to the portal, they will hear it the environment on the other side. To stop portals from finding their own audio, or other portals' audios to be loudest, we made the script ignore all audios played by portals. The sound can be adjusted through the AudioSource, placed on the portal, so that it gradually increases the closer the user walks to the portal and decreases as they walk away from it.

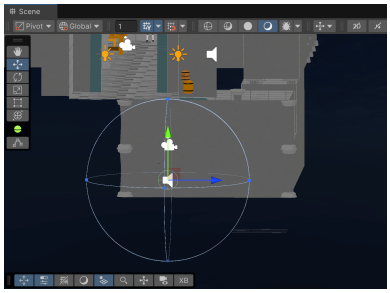

Figure 1: Audio Distance Radius

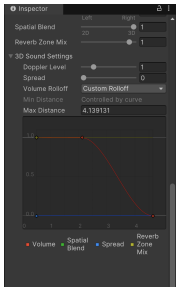

Figure 2: Audio Script Settings

Figure 1 shows the sphere by which we tell the area around the game object that the sound covers, the radius of that sphere can be controlled also by changing a variable called Max Distance in the script as can be seen in figure 2 that shows the inspector. Figure 2 also shows the window in which we can control how the sound is distributed in that area we define, the volume red line shows that we set it such that it starts high near the object and as the user moves further away, it gradually decreases.
For the visual effects, there are 2 designs, a a black and white spiral video and a visual effect that makes the portal look like a window to the new environment. the basic one was the black and white spiral optical illusion; that one was chosen as a basis to test the portal in its simplest form.

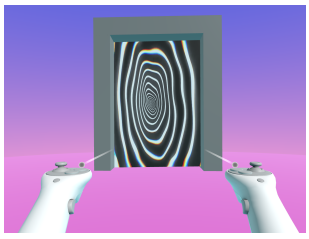

Figure 3: Spiral Effect

Figure 4: See into Other Side

Figure 3, this design features a standard portal with no visual effects; it's implemented by placing a material on the portal in front of the player and setting its albedo to display a video of a spiral optical illusion. Figure 4, illustrates the the alternative visual effect where the user can see into the environment on the other side of the portal. Instead of displaying a static image or video, the material renders a live feed capture by a camera positioned in the target environment behind the target portal. To make it more interactive, a script was implemented on the target portal camera to dynamically replicate the position and rotation of the player's camera relative to the portal they're standing in front of. This translation ensures that the perspective adjusts accordingly, allowing the user to feel as if they're approaching the environment. The effect creates the illusion that the portal is a window into the new environment. A custom shader is used to ensure that the material renders the live feed caption accurately and interactively by making use of the screen-space coordinates and adjusting the texture mapping to align with the player's view in real-time. It also makes use of the shader's ability to compute precise screen positions which adapts the rendering output for each eye in VR which simulates depth perception.

5 Experiement

5.1 Variables

Before conducting our experiement, we came up with our desired independent variables, and dependent variables.

5.1.1 Independent Variables

The independent variables are the variables we will be adjusting through different variations of experiement. We are interested in testing how sounds and visuals affects the participants, therefore our independent variables, will be turning ON/OFF different portal effects. Turning ON/OFF sounds, and turning ON/OFF visuals showing a window to the other side. This will give us four different test scenarios, as seen in figure 5.

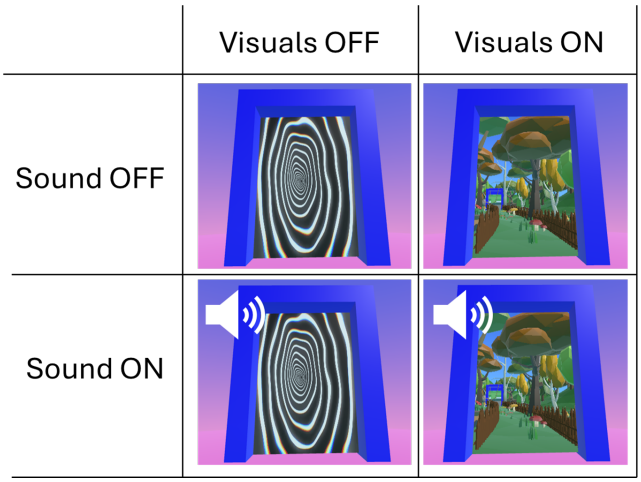

Figure 5: The four different modes for portals

5.1.2 Dependent Variables

There are two dependent variables we mainly wanna observe, *presence*, and *continuity*.
To oberve how our portals affects *presence*, we will utilize the standard IPQ(igroup presence questionnaire) [2] as foundation for assessing presence. Additionaly, inspired by a similar research project [4], we will design three new presence-related questions with focus on portals.
For *continuity* we will again take inspiration from [4], where they designed three questions for this variable. We will make use of those three, and one of our own. We will also ask participants to rate each technique on a scale from 0 to 10 to gather data on their preferences.
All the questions aside from the standard IPQ questions, can be seen below, and the whole questionaire can be seen in appendix (15).

- PRESENCE: The portal technique reminded me that I was in a virtual world.
- PRESENCE: The portal technique made the virtual world become less real.

- PRESENCE: How often did the portal transitions remind you that you were in a virtual environment?
- CONTINUITY: Travelling through the different environments felt like a continuous process.
- CONTINUITY: The portal technique made the different environments feel connected with each other.
- CONTINUITY: The portal technique interrupted my experience in the environments.
- CONTINUITY: Did the visual and auditory design of the portal transitions contribute to a sense of spatial continuity?
- PREFERENCE: In general, how do you rate the portal technique?

5.2 Procedure

To conduct the experiement, we constructed 6 different environments, all connected by portals. It was made by dividing 6 environments into "islands" in our unity scene and placing these islands inside hollow spheres that act as skies for these mini environments. It blocks the user's view of the other environments, and that gives the illusion of traveling to a new seperate world/scene.

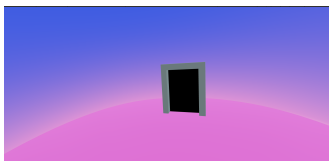

Figure 6: Start Scene

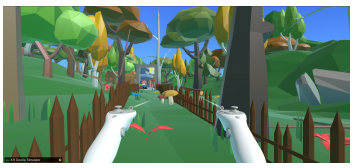

Figure 7: Forest Scene

Figure 8: City Scene

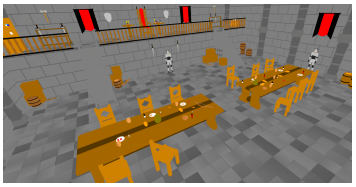

Figure 9: Dungeon Scene

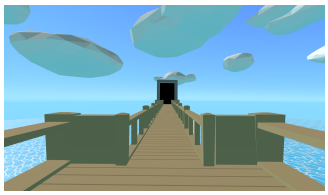

Figure 10: Ocean Scene

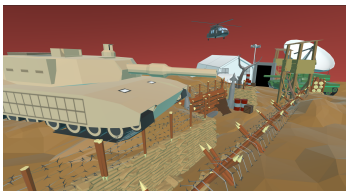

Figure 11: Battlefield Scene

As can be seen in the figure above, we have 6 environments in our experience, a city, a forest, an ocean, a battlefield, a dungeon, and a pink empty scene that serves as our start scene. The goal here is to have the player go through the 6 environments, and go back to beginning. The experiment is to be conducted 4 times, each time we will have the portals set to one of the following modes:

1. No portal audio or visual information (generic transition)
2. Portal visuals only
3. Portal audio only
4. Both audio and visuals enabled for portals.

Before starting the experiement, each participant was asked about their age, gender, and experience with VR, given a consent form, see 16, and an explaination of their task. Their task was to simply walk through the different environments till they reached the starting area(the pink room) again, then take off the headset, and answer an questionnaire. They would have to do this 4 times in total, to test all different modes. To minimize order of effect, we randomized the order in which the different modes for portals would appear. We were not able to randomize the order of environments, meaning the participants would expect the same sequence of evnrionments for each run. This lack of randomization may have caused some biases in our experiement, since the participants would have prior knowledge of what the next environment would be based on memory after the first or second run, instead of just experiencing it through our visual- audio technique.

6 Results

We ran six experiements on a small group of participants, five males, one female, with an average age of 24. Three of the participants had alot of experience with VR, while the other three participants had little to no experience.

After all the tests was conducted, we calculated the average of 7 different values, *Presence*, *Presence(Only IPQ, no Portal presence questions)*, *Spacial Presence*, *Environmental Presence*, *Realim Presence*, *Portal Presence*, and *Continuity*. All of these values was on a likert scale, ranging from -3 to 3, where -3 meant disagreeing, and 3 meant agreeing. The figure below shows all of the presence related values, where we will discuss some of the more interesting parts.

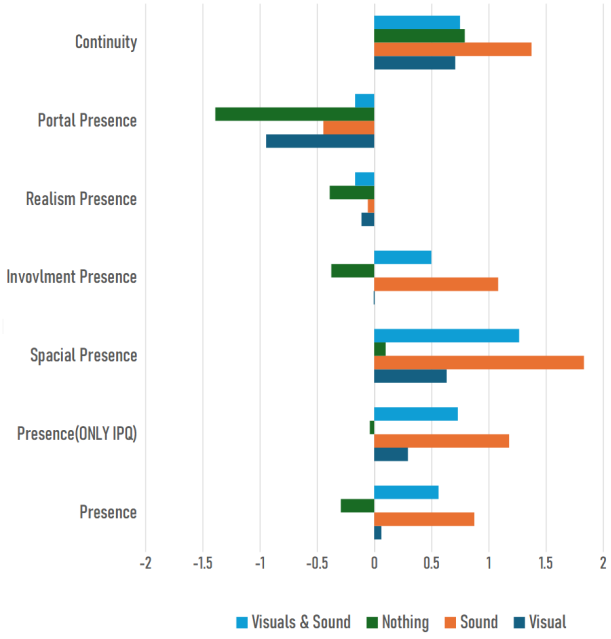

Figure 12: Graph showing the mean of all presence categories, for each portal technique, based on a likert scale from -3 to 3. We should mention that, *Visual* is actually accounted for in *involment presence*, the mean just happen to be exactly 0.

One thing that is immediately noticeable is that the portal with both sound and visuals turned OFF, scored the lowest in all presence categories, so just adding sound or visuals that mimics the other side of portal, already increases presence. Especially when looking at the overall *presence* and *presence (only IPQ)*, here we observe that the portal with both turned off, is the only portal technique that

is actually negative, while all the others are positive.

When comparing the other portals, we notice that the portal with only sound turned on, scored highest in all categories, exept for *Portal Presence*. The portal with both sound and visuals turned on, scored the second highest in all presence categories, and scored the highest in *Portal Presence*.

When we compare overall *Presence* with *Presence (only IPQ)*, we see that *Presence (ONLY IPQ)* is higher for all techniques, so by including the presence questions related to portals in our questionaire, we lower the overall presence. We can clearly see why, when looking at the *Portals Presence* category, where all portals scored a negative value.

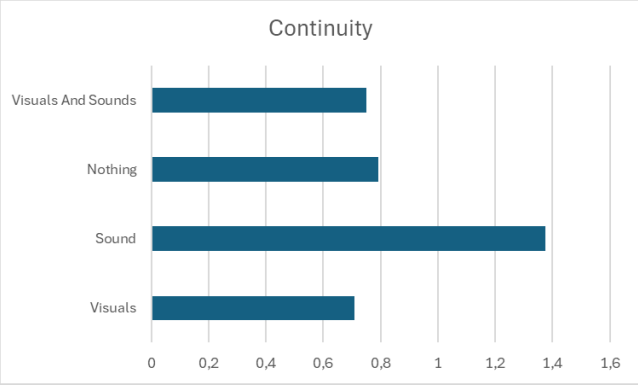

Figure 13: The mean continuity for each portal technique

When we look at continuity for each technique, we observe that all portals, except the portal where only sound was activated, scored around the same mean value(0.71-0.79), while the portal with only sound scored significantly higher(1.38).

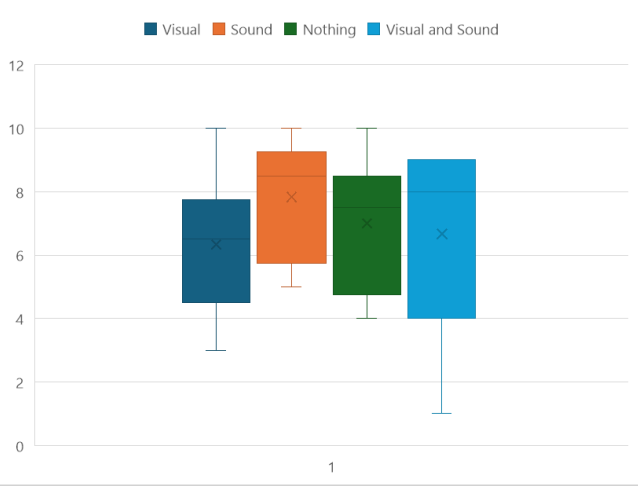

Figure 14: The mean value for preference ratings between 0 to 10 for each technique.

The figure 14 shows box plot for each technique. There was no big difference between the mean values. But we can observe that the portal with only sound, overall did better, and the portal with both sound and visuals, were much more divisive amongts our participants.

Qualitative Feedback

The participants shared a few informal comments on the experience and the portal transition. The comments gave us insight on how camera behavior, visual design and audio cues influenced their experiences.

Many participants noted that the camera feed inside the portal felt ”jittery” or ”trippy”, sometimes leading to discomfort or even mid simulator sickness. One person suggested and would have preferred a static camera view through the portal. On the other hand, the ability to hear destination environment before stepping through the portal was especially highlighted as great by a few, making them able to hear and anticipate what may lay beyond the portal. However, hearing too much of the previous environment’s audio after crossing the threshold disrupted the immersion for a few. One participant commented that persistent lag when looking around the portal made the experience worse, while another found the overall portal visuals, particularly the window effect, great and engaging. Not all participants intially realized that portal audio through the portal was a thing, with one participant only finding out on the last run of the experiment. Overall, the feedback highlights the potential of visual and auditory previews to improve continuity, but also emphasizes the importance to have the right settings and balance for both visuals and audio, across scene transitions.

7 Discussion

The overall positive presence score, see (12), despite the negative values associated with portals in regards to presence might indicate the portals can disrupt presence, but we cannot be completely sure without comparing them to other similar techniques. From papers we have discussed, we can see that portals actually scored the highest in presence [4], so it is more likely, that people just find the act, of transitioning from one environment, to another, to be low on presence. Because of the inherent fictional nature of portals since portals don’t exist in real life, so questions such as ”The portal technique reminded me that I was in a virtual world” will be rated critically, as the concept itself inherently strengthens the artificiality of the experience.

We also saw very low scores in terms of realism presence, this might be due to the level of detail in our virtual environments, which, while visually engaging, were very cartoonish which takes away from the realism factor associated with presence.

Comparing the different portal techniques in regards to presence, see (12), we can see that a visual window, but especially audio window does have a significant role in the feeling of presence for the player in regards to portals, since no visual-audio window consistently scored the lowest. This can especially be seen, in the overall presence, and presence(only IPQ), where no visual or audio had a negative score, while all others had a positive score.

As reported by participants after the experiement as feedback, our specific implementation and design decisions in regards to the portals audio and visuals potentially reduced presence more than it had to. If we had gone a different way of implementing the portals, we might have seen more positive outcomes in regards to portal presence, despite it not being a realistic concept. One alternative method we could have tested for portal visuals could have been making the portal camera static for portals, which could have reduced the feeling of disorentation that some participants experienced in the visualization of the portals. For audio, perhaps fine-tuning it more so that it was easier to know that a specific sound came from the portal, rather than the current environment.

In regards to continuity, see (13), we can see that sound scored the highest, while all the other portal techniques had a similar score. Again, this could be due to the fact that focus went from being on the environment around to the visuals on the portals displaying next environment. Consequently, the player's goal might have shifted to observing the next portal and reaching it rather than exploring the current environment and building anticipation for what's to come. The shift in focus might have prolonged the walking task as participants tended to briefly glance at the environment upon stepping through a portal, only to direct their attention to the next portal for the remainder of the walk.

Lastly, for our preference rating for each technique, see (14), we see the data corporates with our findings above, and that the audio had the biggest on impact on presence, continuity and overall satisfaction. While the portal with both visual and sound, were the most divisive, people either really enjoyed, or did not like it. From the participants feedback, this devisive split is likely because, as we try to mimic the other environment more, people will be more critical, since everything has to be very smooth, so the viewer does not detect any misaligned between the sound and visuals of the portal, and the sounds and visuals of the environment.

8 Conclusion

The experiment evaluated four different portals designs in VR, assessing the user's sense of presence and continuity using the standardized Igroup Presence Questionnaire (IPQ) and additional custom questions tailored for this study.

The results show that incorporating visual or auditory aids into portals design can significantly improve the presence scored compared to the basic portal design; it also weakens their inherently fictional nature, making them more interactive and engaging to the players. The choice of design should be carefully tailored to align with the intended objective. Auditory aids, for example, can enhance suspension and anticipation for what lies beyond the portal, while visual aids are effective in capturing the player's attention and motivating them to approach the portal the portal to discover what awaits on the other side.

Overall, this project shows that seamless, multimodal windows in portals can help reduce perceptual breaks when transitioning between scenes. These results could be experimented with further, creating a portal with an even greater sense of presence, using audio, visuals and interaction design.

9 Contribution Statement

Knzy: Programmed all of the window visual aspects of portals, this includes 2 scripts, and 1 shader. Made the teleportation script. Helped build the city. Tested and debugged most things, and was responsible for the VR-Headset most of the time.

Benjamin : Made the dungeon environment, prepared evaluation by finding participants, and conducting the experiments

Tobias: Made most environments(forest, city, battlefield, ocean, startarea), adjusted sounds, the sound copying script, and the script that changes portals. Conducted experiments.

Everyone worked on the report

10 Appendix

	-3 (disagreeing)	-2	-1	0	1	2	3 (agreeing)
In the computer-generated world I had a sense of "being there"	○	○	○	○	○	○	○
Somehow I felt that the virtual world surrounded me.	○	○	○	○	○	○	○
I felt like I was just perceiving pictures.	○	○	○	○	○	○	○
I did not feel present in the virtual space.	○	○	○	○	○	○	○
I had a sense of acting in the virtual space, rather than operating something from outside.	○	○	○	○	○	○	○
I felt present in the virtual space.	○	○	○	○	○	○	○
How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?	○	○	○	○	○	○	○
I was not aware of my real environment.	○	○	○	○	○	○	○
I still paid attention to the real environment.	○	○	○	○	○	○	○
I was completely captivated by the virtual world.	○	○	○	○	○	○	○
How real did the virtual world seem to you?	○	○	○	○	○	○	○
How much did your experience in the virtual environment seem consistent with your real-world experience?	○	○	○	○	○	○	○
The virtual world seemed more realistic than the real world	○	○	○	○	○	○	○
The portal technique reminded me that I was in a virtual world.	○	○	○	○	○	○	○
The portal technique made the virtual world become less real.	○	○	○	○	○	○	○
How often did the portal transitions remind you that you were in a virtual environment?	○	○	○	○	○	○	○
Travelling through the different environments felt like a continuous process.	○	○	○	○	○	○	○
The portal technique made the different environments feel connected with each other.	○	○	○	○	○	○	○
The portal technique interrupted my experience in the environments.	○	○	○	○	○	○	○
Did the visual and auditory design of the portal transitions contribute to a sense of spatial continuity?	○	○	○	○	○	○	○

In general, how do you rate the portal technique?
0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 ○

Figure 15: Evaluation

Consent Form

By signing this consent form, I agree to allow the project team to process my shared information. Personal data will be collected and processed for the purpose of contributing to a study on the use of portals as a transition device in Virtual Reality (VR).

I am informed that I can withdraw my participation from the project at any time.

Participant's Full Name	Participant's Signature
_____	_____

Figure 16: Consent Form

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