Evaluating the Effects of Experiencing a Mixed Reality Simulation of Symptoms of Schizophrenia on Empathy in Medical Students

Master Thesis

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Abstract

This thesis presents a mixed reality application designed to enhance empathy in medical students towards patients with schizophrenia. The application utilizes mixed reality (MR) technology to immerse users in the experiences of individuals with schizophrenia, allowing them to gain a deeper understanding of the challenges faced by these patients. The study involved a user-centered design approach, incorporating feedback from healthcare professionals to ensure the application's effectiveness and relevance. The results indicate that the MR experience .....
Keywords: mixed reality, empathy, schizophrenia, medical education

Acknowledgements

I would like to express my sincere gratitude to...

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Introduction

The purpose of a report is to transmit coherent information on a subject to the target readers. Reports are usually technical and should be based on verifiable facts or experiments. It is not a chronological description of your work. Obviously, the requirements of your readers (and tutors especially) must be taken into account: what information is requested, how much does the reader know already, what interests him/her? Write your report in such a way that your fellow students will be able to understand it and can put the contained information to use. Try to use short sentences to explain your work rather than long never-ending sentences.

1.0.1 Project Background

Explain the context of your work. Motivate the relevance of your project within its context.

1.0.2 Scope of Project

Explain the scope of your project.

2

State of the Art

This chapter provides a review of the current research on the use of immersive technologies in simulating psychotic symptoms, particularly for the purpose of increasing empathy in healthcare education. It explores how Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) have been applied in educational and also clinical settings, with the focus on schizophrenia. The chapter highlights both the promise and limitations of these technologies, outlines major research gaps and presents evidence that MR is a balanced and potentially more effective tool for empathy training. It also addresses design and ethical considerations which are critical to building realistic and meaningful simulations, and introduces the reasons behind the simulation strategy adopted in this thesis.

2.1 Extended Reality (XR) Technologies

Extended Reality (XR) refers to the spectrum of immersive technologies that blend the physical and digital worlds. This includes Virtual Reality (VR), which fully immerses the user in a computer-generated environment, Augmented Reality (AR), which overlays digital content onto the real world, and Mixed Reality (MR), which combines both, enabling real and virtual elements to interact dynamically. The development and classification of these environments can be understood through Milgram and Kishino's Reality-Virtuality (RV) Continuum, a framework that positions real and virtual environments on a continuous scale, with Mixed Reality covering the space in between. Their accompanying taxonomy further describes experiences along three dimensions: extent of world knowledge (how much the system knows about the real environment), reproduction fidelity (how accurately it replicates real-world perception), and extent of presence metaphor (how naturally users interact within the environment) [29]. In the context of schizophrenia, VR is often used to simulate intense experiences, such as auditory or visual hallucinations, representing psychosis. AR has been applied to embed simulated voices or visual cues into everyday settings, making the experience more relatable. MR, the focus of this thesis, seeks to integrate the strengths of both: allowing users to remain grounded in reality while experiencing interactive, layered symptoms, potentially leading to higher engagement and stronger emotional responses [14, 27, 34].

2.2 Immersive Simulations of Schizophrenia

Immersive simulations have emerged as an important strategy to foster a better understanding of schizophrenia symptoms, as well as to address persistent stigma surrounding the disorder. Virtual Reality (VR) and Augmented Reality (AR) technologies are especially valuable, offering experiential learning environments where participants can "step into the shoes" of individuals experiencing hallucinations, delusions, or cognitive impairments [14]. These approaches have proven to be effective not only in increasing empathy and knowledge but also, in many cases, in reducing stigma among participants [12, 14].

Recent developments have also emphasized the educational use of simulations targeted specifically at healthcare students and professionals, providing controlled, safe, and replicable experiences of psychotic symptoms to better prepare them for real-world clinical interactions [17, 33].

2.2.1 Virtual Reality Applications

Virtual Reality applications in the context of schizophrenia simulations typically seek to recreate sensory and cognitive disturbances through fully immersive experiences. These applications range from fully interactive environments developed with game engines like Unity to 360-degree videos played via head-mounted displays (HMDs) [17, 33].

The use of VR allows users to experience positive symptoms of schizophrenia, such as auditory hallucinations, persecutory delusions, and visual distortions, within a safe environment. Furthermore, VR interventions are now increasingly evaluated for their usability, realism, and educational effectiveness.

2.2.1.1 Simulations of Schizophrenia Symptoms in Medical Training

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A major goal of schizophrenia simulation is to recreate symptoms such as hearing voices, visual hallucinations, or experiencing delusions. For example, studies like those by Zare-Bidaki et al. and Chaffin et al., used VR to create multi-sensory experiences, combining sound, visuals, and interaction to simulate intense delusions and internal voices [6, 34]. Importantly, Zare-Bidaki et al.'s participants were medical students tasked with simulating the experience of a psychotic episode to enhance their clinical empathy and understanding. Silverstein et al. and van Ommen et al. looked at how people with schizophrenia might see distorted images, such as unfamiliar faces, strange objects, or unreal environments [28, 31]. However, it is important to clarify that their works primarily explored the phenomenology and neurobiology of visual hallucinations in clinical schizophrenia, not through VR simulations, and not directly in educational interventions for students. Nonetheless, these insights become incredibly important, and were also heavily used for the design of the simulation created in this project, as they help to create a more realistic and relatable experience for users.

Furthermore, some tools are made specifically for training in medical and nursing education. Yoo et al. and Lee et al. developed VR training programs using 360-degree video and actors to recreate clinical situations [17, 33]. The primary goal was to simulate encounters with patients exhibiting psychiatric symptoms in acute hospital settings. These tools largely rely on passive observation within pre-recorded 360° videos, meaning that while users can look around and witness events unfold, direct interaction with the environment is usually limited. Thus, while they offer vivid emotional realism, they often lack deep interactivity. These simulations included symptoms like hearing voices or patients behaving aggressively and were shown to be realistic and useful for learning. Kuhail et al. (2022) and Domnick et al. developed similar VR tools for medical students, which helped increase understanding and reduce stigma [8, 15].

2.2.1.2 Research Gaps

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While immersive technologies have become increasingly valuable for simulating schizophrenia symptoms, existing research remains heavily focused on VR. Among the broader XR spectrum, VR is by far the most studied and widely applied method, leaving AR and MR comparatively underexplored [15].

For instance, a systematic review by Holopainen et al. examined 12 studies using VR-based interventions for schizophrenia, including cognitive behavioral therapy (CBT) or social skills training. These studies reported positive outcomes across a range of symptoms — such as hallucinations, paranoia, and cognitive difficulties — with minimal adverse effects. Notably, none of the reviewed interventions utilized AR or MR, further showing the gap in the literature [12].

Similarly, Lan et al. reviewed a large number of articles and found that, while VR continues to show promise in these medical settings, there was no evidence of AR or MR being tested in medical trials for psychosis. Despite the many advantages these technologies could offer — particularly MR, which allows for immersive symptom simulation while keeping users aware that they remain in the real world [16].

This gap presents a good opportunity to explore MR as an alternative approach, especially for applications with the focus on empathy development. MR has the potential to provide emotionally engaging yet psychologically safer experiences than fully immersive VR. The following section highlights existing studies that have begun to explore AR and MR in schizophrenia education, and sets the foundation for the MR-based approach developed in this thesis.

2.2.2 Augmented and Mixed Reality Applications

2.2.2.1 Key Studies

An increasing number of studies are exploring the use of AR and MR in schizophrenia education. One early - and for this thesis very relevant - example is by Silva et al. (2017), who created a tool using AR to simulate psychotic symptoms. This system, developed with input from psychiatric professionals, was designed to help users — especially medical students — better understand schizophrenia and reduce stigma. The AR tool allowed users to interact with simulated symptoms in real time, providing a safe and controlled learning environment [27]. To test the system, 21 medical students used AR glasses (HMZ-T2, Sony glasses *ref?*) to experience the simulation. Afterward, they filled out questionnaires about their attitudes toward schizophrenia, how realistic they found the experience, and whether their views had changed. Students gave high ratings for the audio quality and educational value of the simulation. Many said it helped them better understand what psychotic experiences might feel like. However, some users also reported problems, such as discomfort from the equipment and difficulty focusing in the environment [27].

The simulations impact on empathy and stigma was measured using questionnaires before and after the experience. The results showed that students felt more empathy, expressed more concern for a fictional patient, and were more willing to help. However, there was also a small increase in stigma scores, showing that the results were complex. The study suggests that while AR can help increase empathy, future designs should focus on improving comfort and exploring long-term effects [27]. It also recommends combining simulations with brief educational sessions on schizophrenia to deepen understanding [27].

Another very relevant study by Skoy et al. created a simulation where users hear disturbing voices through headphones to better understand the kind of confusion and distraction that people with schizophrenia may deal with [30]. The simulation used Patricia Deegan's "Hearing Distressing Voices" audio track

— based on her personal experience with schizophrenia — and was paired with practical tasks. Students completed these while listening to disturbing voices through headphones, mimicking real-life challenges. After the simulation, students took part in a debriefing and completed reflective writing. Results showed a significant increase in empathy scores.

A more recent project by Krogmeier et al. involved the development of *Live-It*, an AR simulation that used the passthrough function of the Meta Quest 3 headset. This system simulated hallucinations and delusions in familiar places like living rooms or pharmacies. The design was based on real-life experiences from individuals with schizophrenia and was reviewed by neuropsychologists to ensure accuracy [14]. Participants in the study - mainly students and professionals in mental health — reported strong emotional reactions and said the simulation helped them better understand schizophrenia symptoms. One of the strengths of *Live-It* was its ability to place symptoms into everyday situations, which made the experience feel more realistic and less overwhelming than fully immersive VR. For example, users heard voices that ranged from critical to supportive, reflecting the variety of hallucinations people might experience. The simulation also ended with hopeful messages, which helped balance the emotional impact. Overall, the study found that *Live-It* increased empathy and encouraged participants to support individuals with schizophrenia. It showed that AR can be a powerful tool in mental health education, especially when it helps bridge the gap between theory and real-life experience [14].

2.2.2.2 Technical Advantages

AR/MR simulations place symptoms in real-world settings, which can reduce user discomfort and improve relatability. These simulations tend to be less intense than full VR, making them more accessible to first-time users or those unfamiliar with immersive technology. One useful feature is passthrough, a technology that allows users to see their actual surroundings through cameras on the headset while digital content is overlaid on top. This helps users stay oriented and grounded in the real world while still experiencing simulated symptoms, which may enhance engagement while minimizing sensory overload. Features like passthrough may help enhancing empathy without overwhelming users [14, 16, 27].

2.3 Empathy in Healthcare Education

2.3.1 Definition of Empathy

Empathy is a key part of good communication and care in healthcare. Many studies have shown that when healthcare professionals show empathy, patients are more satisfied, more likely to follow treatment plans, and often have better mental health outcomes [7, 22, 23]. In medical and nursing education, empathy is no longer seen as just a ”soft skill.” It is now treated as something important that can be taught and developed. Teaching empathy helps improve the way future professionals connect with patients and provide care [7].

Empathy is usually described as having two main parts: *cognitive empathy* and *affective empathy*. Cognitive empathy is the ability to understand what someone else is thinking or feeling. Affective empathy means actually feeling or emotionally connecting with what the other person is going through [19, 32]. In healthcare, both types are important. Understanding a patient's perspective (cognitive empathy) helps with communication and decision-making, while emotional connection (affective empathy) helps build trust and stronger relationships [7, 23].

Understanding this and training empathy helps doctors and nurses better understand their patients and respond in helpful and compassionate ways [22, 23]. However, research has shown that empathy can decrease during medical training. This might be because students are under pressure, focusing more on technical knowledge, or feeling emotionally drained [20, 23]. This decline in empathy can lead to negative outcomes for both patients and healthcare professionals. Patients may feel misunderstood or neglected, while healthcare providers may experience burnout and job dissatisfaction [7, 20]. Therefore, it is crucial to find effective ways to teach and maintain empathy in medical education.

2.3.2 Measuring Empathy

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Various instruments are used to measure these dimensions of empathy, including the Jefferson Scale of Empathy (JSE), which is being widely applied in medical education [1]. This tool allows researchers to assess changes in empathy following interventions and distinguish between shifts in emotional versus cognitive components, which is also what I want to achieve in this thesis. In the context of this thesis, the JSE will be used to measure the impact of the MR simulation on medical students' empathy levels. The JSE is a validated instrument that has been widely used in medical education research and has demonstrated reliability and validity in assessing empathy in healthcare professionals [11]. By employing the JSE, this study aims to provide a comprehensive evaluation of the effectiveness of the MR simulation in enhancing both cognitive and affective empathy among medical students. In Chapter *reference to results and analysis chapter*, we will discuss the results of the JSE and how they relate to the overall objectives of this thesis.

2.3.3 Immersive Technologies and Empathy

2.3.3.1 Empathy Increase through Virtual Reality

Virtual Reality (VR) has often been called the ”ultimate empathy machine” because it can create powerful first-person experiences in fully immersive environments [21]. Several studies support this idea, showing that VR can have a strong emotional effect on users.

VR is especially useful when it comes to helping people understand the experiences of stigmatized groups, such as individuals with schizophrenia [10, 18, 20]. These systems allow users to go through simulated versions of symptoms like hearing voices or feeling paranoid. By placing users in situations that reflect what it might be like to live with psychosis, these simulations aim to increase empathy and reduce negative attitudes. For example, Formosa et al. (2018) found that people who used a VR simulation of schizophrenia symptoms felt more empathy and showed less stigma afterwards compared to those who did not use the simulation [10]. A similar study by Hsia et al. (2022) showed that pharmacy students who experienced auditory hallucinations in VR also became more empathetic and less stigmatizing toward people with schizophrenia [13]. One crucial reason for this was that the students also heard from a guest speaker diagnosed with schizophrenia after they have experienced the simulation. This combined approach helps address one of the main concerns with simulations — that they can unintentionally increase social distance or reinforce stereotypes if not supported by real-life context. Including authentic human interaction can make the experience more meaningful and well-rounded. In this thesis we will also include a debriefing session after the simulation, where students can reflect on their experiences and discuss them with peers and instructors. This is important for helping students process what they have learned and apply it to real-life situations [13].

The immersive tools discussed in this thesis are being tested in medical and nursing schools as a new way to teach empathy by letting students “step into the shoes” of patients [1]. As mentioned earlier, this approach is becoming more popular in education and has shown promising results.

2.3.3.2 Empathy Increase through Mixed Reality

MR is gaining attention as a promising alternative to VR in empathy-focused education, particularly in mental health contexts. Unlike VR, MR allows users to remain partially connected to their physical surroundings while engaging with digitally simulated symptoms. This hybrid approach combines the immersive power of VR with the real-world anchoring of AR, helping to reduce sensory overload and making experiences more relatable and less overwhelming [34].

Studies by Silva et al. (2017) and Krogmeier et al. (2024), which were already discussed in detail in section 2.2.2.1 demonstrate the effectiveness of MR in increasing empathy and understanding toward individuals with schizophrenia. In both cases, simulations placed users in familiar environments while layering auditory and visual hallucinations over the reality. Participants reported strong emotional engagement and a clearer understanding of what it might be like to experience psychosis [14, 27].

Together, these insights reinforce the central aim of this thesis: to evaluate MR as a balanced and effective tool for simulating psychotic experiences in medical education. By allowing users to engage empathetically with symptoms while staying cognitively oriented, MR may better support both affective and cognitive empathy development. Its ability to blend emotional immersion with realism makes it especially well-suited for sensitive topics like schizophrenia, where responsible storytelling and psychological safety are essential.

2.3.4 Limitations in Empathy Training

Martingano et al. (2021) reviewed 43 studies and found that while VR often enhances affective empathy, its effect on cognitive empathy is less consistent [19]. They argue that immersive experiences might reduce the user's need to mentally simulate another's perspective, as the simulation does that work for them. Without reflection or guided discussion, users may have strong emotional reactions but fail to develop deeper understanding.

Similarly, Rueda and Lara (2020) caution against relying on emotional responses alone. They call for "reason-guided empathy," which integrates critical thinking and ethical reflection into simulation-based learning [26]. Without this, empathy may be short-lived or biased.

The findings also show that more expensive or immersive setups do not necessarily yield better outcomes. Thoughtful design and context are incredibly important. Many VR simulations rely heavily on dramatic intensity, which can restrict the ability of the user to reflect or exercise perspective-taking — the cognitive process of imagining the world from another person's viewpoint, which is essential for developing empathy and reducing bias [20]. This limitation further supports the use of MR paired with preparation and debriefing, as adopted in this thesis.

Ozcan et al. tracked empathy development in nursing students over four years. While communication skills improved, emotional empathy declined—likely due to burnout or emotional distancing [23]. This underlines the importance of designing empathy training that includes emotional support and reflection. The MR simulation in this thesis builds on that principle.

Finally, as mentioned repeatedly, ethical concerns remain. VR simulations can unintentionally reinforce negative stereotypes if not carefully framed. Being incredibly affected by something, without deeper context, may lead to bias or stigma [26]. MR used in the real world, along with structured pre- and post-simulation activities, is intended to reduce this risk. The approach in this thesis prioritizes both emotional resonance and cognitive clarity to improve thoughtful empathy in clinical learners.

2.4 Simulation Design Considerations

2.4.1 Empathy and Usability

Immersive simulations offer powerful opportunities to increase empathy in medical education, particularly for conditions like schizophrenia. However, designing effective simulations requires careful attention to realism, emotional impact, and usability.

Marques et al. compared a VR simulation of psychosis with a standard 2D video and found that the VR group experienced greater gains in cognitive empathy and held more positive attitudes toward individuals with schizophrenia. However, the study also noted several limitations: it lacked a control group and did not measure perceived immersion — a key factor in empathy development. Some participants also struggled with unfamiliarity with the technology [18].

Similarly, Zare-Bidaki et al. found that VR simulations of psychosis led to higher empathy and stigma reduction compared to traditional patient visits. However, they emphasized that simulations should supplement—not replace—direct human interactions. Authentic contact provides depth, variability, and personal meaning, which simulations alone cannot replicate [13, 34].

Both studies emphasize that simulations must balance engagement and emotional intensity without overwhelming participants. Overly dramatic portrayals of symptoms — such as frightening hallucinations or paranoia — can trigger distress, increase social distance, or reinforce harmful stereotypes if not properly contextualized [2, 6, 34].

To reduce this risk, Zare-Bidaki et al. recommend using calm, familiar environments and grounding simulations in lived experience. They also suggest that AR or MR, which preserve awareness of the real world, may help avoid overstimulation while still enabling emotional immersion [34]. This aligns with the approach taken in this thesis, which uses MR to simulate symptoms in relatable real-world contexts. The use of passthrough features allows participants to remain anchored while interacting with hallucination overlays, aiming to foster empathy without sensory overload.

2.4.2 Ethical Challenges

While immersive simulations hold great promise for enhancing empathy, they also raise important ethical and psychological concerns—particularly in the context of mental health education as seen in the previous sections. Many studies suggest that emotional impact alone does not guarantee positive attitudinal change and may, in some cases, amplify discomfort or misunderstanding [2].

These findings highlight the critical importance of proper preparation and debriefing. Without guided reflection, users may interpret psychotic symptoms in simplistic or fear-based ways, reinforcing stereotypes about schizophrenia. Ando et al. and Rueda and Lara both advocate for what they call a *reason-guided empathy*, a model in which emotional engagement is supported by ethical reflection and cognitive understanding. This approach encourages users not only to feel compassion but also to think critically about the lived experience of mental illness [2, 26].

Another important ethical issue has to do with how the simulation is designed. Using very realistic effects—like intense visuals, surround sound, and dramatic symptoms—can make the experience feel more lifelike. But for some users, especially those not used to immersive technology, this can be overwhelming. Also, trying to show a “typical” psychotic episode can be problematic, since symptoms vary a lot from person to person. This could lead to a simplified or even misleading picture of what schizophrenia is really like [34].

It iss also essential to think about how the story behind the symptoms is presented. If the simulation focuses only on fear or confusion without any background or explanation, it might unintentionally make people with schizophrenia seem dangerous or unstable. This can reinforce negative stereotypes. Rueda and Lara warn that mental health simulations need to be told in a responsible way—showing the human side of the experience, not just the symptoms [26].

In conclusion, When used alongside proper educational materials and opportunities to reflect on the experience, MR can help build deeper, more respectful empathy. This is a key part of the design approach taken in this thesis.

2.4.3 Simulation Design Strategy

To address the challenges mentioned above, this thesis adopts a design strategy that:

- Uses Mixed Reality to simulate schizophrenia symptoms in familiar environments, allowing users to remain grounded in reality
- Tests the simulation on medical students which already have had a preparatory educational session to provide context and understanding of schizophrenia, reducing the risk of reinforcing stigma
- Includes a debriefing session to help with reflection, discussion, and ethical understanding of the experience
- Measures perceived immersion and empathy outcomes to evaluate the impact of the simulation on students' attitudes and understanding
- Uses a combination of auditory and visual hallucinations to create a layered experience that reflects the complexity of real-life symptoms
- Uses a gradual increase in emotional intensity, allowing users to acclimate to the experience without overwhelming them
- Engages students in a reflective process that encourages them to connect their experiences to real-life clinical practice and patient interactions

By doing so, this approach aims to increase both affective and cognitive empathy in medical students — helping them not only to feel what patients go through, but also to understand their experiences within a respectful and informed framework.

Table 2.1: Overview of studies used for this thesis

Title	Year	Study Design	Tools Used (VR/AR/MR)	Target Group	Symptom Experience	Empathy or Stigma	Cognitive Empathy Increased	Affective Empathy Increased	Main Results
Developing empathy in nursing students: a cohort longitudinal study	2012	Cohort longitudinal	None (Traditional education methods)	Nursing students	General emotional and communication contexts	Empathy	Yes	Yes	Empathy improved significantly in women through targeted training; results less clear for men
Impact of a Virtual Reality-Based Simulation on Empathy and Attitudes Toward Schizophrenia	2022	Quasi-experimental	VR	Health students	Simulated psychotic symptoms	Both	Yes	Possibly	VR more effective than 2D video in enhancing empathy and reducing stigma
Empathic Mixed Reality: Sharing What You Feel and Interacting with What You See	2017	Experimental (early studies)	MR (AR + VR)	General users (not specified)	Emotion sharing, collaboration	Empathy	Possibly	Yes	MR enabled physiological and emotional data sharing; promising for collaborative empathy
Nursing Students' Experiences of Empathy in a Virtual Reality Simulation Game	2024	Descriptive qualitative	VR	Nursing students	Virtual patient care	Empathy	Yes	Yes	VR helped students experience and express empathy effectively
Virtual Reality as a Medium to Elicit Empathy: A Meta-Analysis	2020	Meta-analysis	VR	Various populations	Multiple contexts	Empathy	Yes	Unclear	Perspective-taking improved; general empathy results were mixed
Improving Empathy in Nursing Students: A Comparative Longitudinal Study of Two Curricula	2018	Comparative longitudinal	None (Traditional vs. integrated curriculum)	Nursing students	General emotional and clinical context	Empathy	Yes	Decreased over time	Integrated curriculum more effective; empathic skills improved but tendency declined
Relationships Between Nurse–Expressed Empathy, Patient–Perceived Empathy and Patient Distress	1995	Correlational study	None (standard clinical practice)	Nurses and patients	Real-life distress in hospital settings	Empathy	Not applicable	Not applicable	Nurse-expressed empathy positively correlated with perceived empathy; reduced patient distress
Testing the efficacy of a virtual reality based simulation in enhancing users' knowledge, attitudes and empathy relating to psychosis	2018	Experimental pre-post	VR	General public, psychology students	Simulated psychotic symptoms	Both	Yes	Yes	VR simulation significantly increased empathy, knowledge, and improved attitudes
Virtual Reality and Empathy Enhancement: Ethical Aspects	2020	Theoretical/Review	VR	General (conceptual discussion)	Not specific (broad scenarios)	Empathy	Possibly	Possibly	Explores philosophical and ethical aspects; emphasizes reason-guided empathy over immersive emotion
Effectiveness of immersive virtual reality in teaching empathy to medical students	2024	Mixed methods (pre-post + interviews)	VR	Medical students	Social isolation in older adults	Empathy	Yes	Yes	Empathy significantly increased post-training; immersion and embodiment were key factors
VR Improves Emotional but Not Cognitive Empathy: A Meta-Analysis	2021	Meta-analysis	VR	General population	Various contexts	Empathy	No	Yes	VR improved emotional empathy but not cognitive empathy; not more effective than low-tech methods

Title	Year	Study Design	Tools Used (VR/AR/MR)	Target Group	Symptom Experience	Empathy or Stigma	Cognitive Empathy Increased	Affective Empathy Increased	Main Results
Use of an Auditory Hallucination Simulation to Increase Student Pharmacist Empathy	2016	Pre-post experimental	Audio simulation	Pharmacy students	Auditory hallucinations	Empathy	Not measured	Yes	Empathy increased; students reported distraction and frustration during task
Reducing the Schizophrenia Stigma: A New Approach Based on Augmented Reality	2017	Quasi-experimental	AR	Medical students	Psychotic symptoms simulation	Stigma	Not measured	Not measured	AR experience reduced stigma and improved understanding of schizophrenic symptoms
Leveraging AR for Understanding Schizophrenia	2024	Thematic evaluation (qualitative)	AR	Healthcare students, experts	Hallucinations, delusions, disorganized behavior	Stigma	Possibly	Possibly	Participants better understood schizophrenia; highlighted as an educational tool
The Virtual Doppelganger: Effects of a Virtual Reality Simulator on Perceptions of Schizophrenia	2010	Between-subjects experiment (4 conditions)	VR	General public	Schizophrenia symptoms	Both	Yes (in combo with empathy set)	Yes	Empathy + VR condition most effective; VR-only increased social distance
Immersive VR Applications in Schizophrenia Spectrum Therapy: A Systematic Review	2020	Systematic review	VR	Patients with schizophrenia spectrum disorders	Delusions, hallucinations, cognitive/social issues	Empathy (implied), Therapy	Not directly measured	Not directly measured	VR showed promising results for therapy; safe and well tolerated
Efficacy of Immersive XR Interventions on Symptoms of Schizophrenia Spectrum Disorders	2023	Systematic review	XR (VR)	Patients with schizophrenia	Various psychotic symptoms	Empathy (secondary), Therapy	Not focus	Not focus	VR effective across symptom domains; no AR studies found
Impact of an Auditory Hallucination Simulation Coupled with a Speaker Diagnosed with Schizophrenia	2022	Pre-post with speaker intervention	Audio simulation	Pharmacy students	Auditory hallucinations	Stigma	Not focus	Not focus	Stigma reduced significantly, especially in attitudes and disclosure openness
Representing Mental Disorders with Virtual Reality: Goliath	2023	Case study analysis (artistic VR)	VR	General public	Narrative VR of schizophrenia	Empathy	Yes	Yes	Focused on ethical, artistic VR design for empathy through embodiment
The Simulation of Hallucinations to Reduce the Stigma of Schizophrenia: A Systematic Review	2011	Systematic review	Simulation (audio/VR)	Mixed (students, general public)	Hallucination simulation	Stigma	No	Yes	Increased empathy, but also social distance; ethical considerations advised
Creating Empathy Through Use of a Hearing Voices Simulation	2013	Mixed methods (pre-post and reflection)	Audio simulation	Psychiatric nursing students	Auditory hallucinations	Empathy	Not measured	Yes	Empathy significantly increased; students reported transformation in attitude and care approach
Out of Touch with Reality? Social Perception in First-Episode Schizophrenia	2013	fMRI observational study	None (neuroimaging)	Schizophrenia patients	Tactile and social perception stimuli	Empathy	Impaired (linked to self-other confusion)	Not measured	Impaired neural mechanisms for social touch perception; linked to empathy deficits
Immersive Simulation of Schizophrenia	2023	Development and evaluation project	VR	General public / students	Visual and auditory hallucinations	Stigma	Possibly	Possibly	VR simulation aimed to reduce stigma; immersive experience showed promise for education

Title	Year	Study Design	Tools Used (VR/AR/MR)	Target Group	Symptom Experience	Empathy or Stigma	Cognitive Empathy Increased	Affective Empathy Increased	Main Results
Learning by Doing: Educational VR for Care of Schizophrenic Patients	2020	Design and usability study	VR (360 video, HMD)	Nursing students	Various schizophrenia symptoms (hallucinations, delusions)	Empathy	Possibly	Yes	Participants reported increased empathy and engagement; useful educational platform
Evaluating VR Simulation of Psychosis on Stigma, Empathy, and Knowledge	2022	Controlled experimental	VR	Medical students	Psychotic symptoms	Both	Yes	Yes	VR significantly more effective than ward visits at increasing empathy and reducing stigma
Usability of Mental Illness Simulation via Immersive VR	2020	Mixed methods usability study	VR	Nursing students	Schizophrenia symptoms	Empathy	Possibly	Yes	Students found simulation realistic and engaging; suggested for broader use in nursing education
Visual Hallucinations in Psychosis	2019	Clinical observational study	None	Psychosis patients	Visual hallucinations (VH)	Empathy (implied)	Not measured	Not measured	VH are diverse and vivid; associated with reduced insight and fear; linked to stigma and distress
Visual Distortions and Hallucinations in Schizophrenia: An Update	2021	Literature review	None	Schizophrenia patients	Visual hallucinations and distortions	Empathy (conceptual)	Not directly assessed	Not directly assessed	Explores mechanisms and clinical impact of visual symptoms; calls for targeted interventions

3
Methodology

In this chapter, I present the methodology used to design, implement, and evaluate a MR simulation aimed at increasing empathy toward individuals diagnosed with schizophrenia. Building on the gaps and opportunities identified in the state of the art (Chapter 2), this study explores whether a brief MR simulation of symptoms—lasting approximately 4–5 minutes—can significantly influence both *affective* and *cognitive* empathy among medical students. The approach combines immersive technology, tested on medical students which already have experience with patients and know about schizophrenia and its symptoms, and guided debrief to examine how such a simulation may reshape students' perceptions and attitudes toward people with schizophrenia.

3.1 Research Question

The central research question of this project is:

> ***Can a short Mixed Reality simulation of schizophrenia symptoms effectively increase both affective and cognitive empathy in medical students, and influence their perception of individuals diagnosed with schizophrenia?***

This question emerges from several key insights presented in the state of the art:

- VR has been shown to enhance affective empathy, but its effects on cognitive empathy are inconsistent [19, 32].
- MR remains underexplored, yet early studies suggest it can balance immersion and realism, potentially supporting more empathetic outcomes [14, 27].
- Ethical concerns require immersive experiences to be framed through knowledge delivered beforehand and reflection/debriefing after the simulation to avoid stigma or stereotype reinforcement [2, 26].

3.2 Using Mixed Reality

Based on the literature review, MR offers several advantages over VR in the context of schizophrenia simulations, making it a particularly suitable choice for this thesis. One of the most important benefits of MR is its ability to provide emotional safety through real-world grounding. Unlike fully immersive VR, which can sometimes overwhelm users with intense sensory input, MR allows participants to remain anchored in their actual environment. This helps reduce the risk of distress that has been reported in VR-based schizophrenia simulations, especially when simulating frightening symptoms [34].

MR also offers higher relatability and engagement by integrating hallucinations and delusional content into familiar, everyday settings, such as a classroom. This contextualization can enhance the emotional resonance of the experience, as users are more likely to connect with scenarios that resemble their own daily environments [14]. Rather than experiencing psychotic symptoms in abstract or exaggerated virtual spaces, participants see these symptoms unfold in realistic and meaningful contexts, increasing the perceived authenticity of the simulation.

Furthermore, MR supports a more balanced approach to empathy training by addressing both cognitive and affective components. While VR often elicits strong emotional reactions, MR allows users to emotionally engage with the simulation while still having the cognitive space to process and reflect on what they are experiencing. This engagement is particularly valuable in educational settings, where the goal is not only to generate emotional impact but also to foster a deeper understanding of the condition which is being simulated [19, 26].

From a technical perspective, MR provides flexibility through the use of modern headsets equipped with passthrough functionality, such as the Meta Quest 3[1]. This device enables the user to see their environment, onto which simulated symptoms can be layered in real time. This technology enables the development of dynamic and responsive simulations that feel both immersive and real.

3.3 Participants and Procedure

The target group for this study consists of medical students in their preclinical or early clinical training, specifically from the University of Health in Fribourg, Switzerland (in French: Haute école de santé Fribourg, HEdS-FR). This population was selected for two primary reasons. First, students at this stage are actively developing their clinical attitudes, including their capacity for empathy toward patients. Second, previous research has shown that empathy training tends to be particularly effective during this formative period in a healthcare professionals education [13, 15].

Participation in the study is voluntary, and all participants are recruited through internal communication channels within the university. Before taking part, each participant receives comprehensive information about the objectives of the study, its procedures, and potential risks. They are informed of their rights, including the ability to withdraw at any time, and are asked to sign a written consent form confirming their understanding and agreement.

The study is conducted in small groups. A total of five groups, each consisting of six students, participate in the simulation sessions. Within each group, only one student wears the MR headset and experiences the simulated symptoms. The other five students remain in the room during the simulation and are given a specific task by the instructor. Their role is to observe the behavior of the participant wearing the headset, noting any signs of confusion, distraction, or distress. This setup serves two purposes: first, it mirrors real clinical scenarios where healthcare providers must interpret subtle behavioral cues; and second, it allows researchers to explore whether witnessing someone elses simulated experience can also affect empathy and perception from an external, observational perspective.

[1]Meta Quest 3 is a standalone mixed reality headset developed by Meta Platforms, released in October 2023. For more information, see: `https://www.meta.com/quest/quest-3/`

All six group members—both the headset user and the observers—complete the same set of questionnaires. These include the Jefferson Scale of Empathy (JSE) [11] to assess baseline and post-simulation empathy levels, and the Brief Positive and Negative Affect Schedule (B-PANAS) [5] to measure emotional responses and perceptions toward individuals with schizophrenia. The evaluation process is described in more detail in Chapter 3.5.

The simulation itself lasts approximately 4 to 5 minutes. During this time, the student wearing the headset is exposed to a carefully sequenced combination of auditory and visual hallucinations, all set within a familiar environment such as a classroom. The goal is to simulate psychotic symptoms in a way that is immersive but safe, and to encourage emotional and cognitive engagement with the experience.

Immediately following the simulation, all group members take part in a structured debriefing session moderated by teaching staff. This guided reflection allows participants to discuss what they observed or experienced, process their emotional responses, and relate the exercise to their future clinical work. For the observers in particular, this provides an opportunity to articulate how witnessing the simulation affected their perception of both the symptoms and the individual undergoing them.

After the debriefing, participants once again complete the JSE and B-PANAS questionnaires to assess any changes in empathy levels and emotional responses. They are also invited to provide qualitative feedback on the simulation, including comments on its realism, emotional impact, and educational value. The inclusion of both direct and indirect participants allows the study to assess how empathy might be influenced not only by immersive first-person experiences, but also through empathetic observation—a dimension that has received limited attention in the literature.

To conclude this chapter, by combining known MR technology with carefully structured educational framing, observation-based group dynamics, and post-simulation reflection, this thesis seeks to explore a multi-layered approach to empathy training in medical education. The methodology builds on known challenges and recommendations from the literature, such as avoiding emotional overload, reinforcing context, and ensuring accurate, respectful depictions of schizophrenia.

3.4 Simulation Design

The MR simulation developed in this thesis was designed to give students an emotional and realistic sense of what it might feel like to experience psychotic symptoms, while still keeping them in their real environment. Unlike VR, which fully replaces the users surroundings, MR allows digital symptoms — like hallucinations or sounds — to appear in the users actual space.

The simulation shows both auditory and visual symptoms, based on real descriptions from people who live with schizophrenia. Users hear critical or unsettling voices and see visual changes with the goal of distracting them. These effects are introduced step by step to reflect how symptoms often build gradually. The aim is not to scare or shock, but to help students connect with the emotional and mental confusion that someone with psychosis might feel.

Because the simulation is only 4 to 5 minutes long, it focuses on giving a short but meaningful experience. It is placed in a familiar environment, which is the classroom, so that the symptoms feel more relatable. This balance is important: the goal is to increase empathy and understanding, not to create fear or reinforce negative stereotypes.

To support this, the simulation is framed by two key points. Before the day of testing, students have already been lectured sometime in their studies on the topic of schizophrenia and also already have pracitcal experience with patients. They also will be briefed about the simulation and what it should show. Afterwards, they take part in a guided debrief, where they can reflect on how they felt, what they learned, and how it might change the way they see or interact with patients. This step is especially important, as it helps students process the experience in a thoughtful way.

The overall design is based on ideas from recent research, which shows that immersive tools work best when combined with education and reflection. Studies by Rueda and Lara (2020) and Zare-Bidaki et al. (2022) stress that simulations should be realistic and meaningful, but also ethically responsible and emotionally safe. This approach follows those recommendations closely, aiming to create a learning experience that supports both emotional connection and critical thinking [26, 34].

3.5 Evaluation and Data Collection

To assess the impact of the MR simulation on students empathy and emotional understanding of schizophrenia, this study uses a combination of quantitative self-report measures and reflective feedback. The aim is to capture not only changes in empathy levels, but also students emotional responses and perceptions of the simulations realism and educational value.

Since the study was conducted at a French-speaking institution, all materials, including consent forms, questionnaires and the simulations audio, were provided in French to ensure accessibility and clarity for participants.

3.5.1 Jefferson Scale of Empathy (JSE)

The primary tool used to measure empathy is the Jefferson Scale of Empathy (JSE), which is widely applied in medical education and has been shown to reliably measure both affective and cognitive components of empathy [11]. The JSE is administered before and after the MR simulation to assess whether the experience has led to measurable changes in students' empathy levels. The results are analyzed to determine changes in total empathy scores, as well as shifts in cognitive and affective empathy dimensions.

Since the JSE was originally developed in English and no officially validated French version was available for this study, the questionnaire was translated into French by the researcher using a combination of online translation tools and manual adjustments. While care was taken to preserve the meaning and intent of the original items, this translated version has not undergone formal psychometric validation. As such, the use of this adapted French version represents a methodological limitation and should be considered when interpreting the results.

To better align the measurement tool with the goals of this study—namely, to evaluate both cognitive and affective components of empathy in a balanced and time-sensitive way—the full JSE was thematically reviewed and categorized by the author. Based on an in-depth literature review and the conceptual definitions of empathy used in this thesis, each item was classified as either *Cognitive* or *Affective*. Cognitive items reflect an emphasis on understanding the patient's perspective, thoughts, or non-verbal cues, while affective items relate to emotional awareness, resonance, or the therapeutic value of emotional understanding. A detailed overview of this classification can be found in Appendix A, Table A.1.

In order to maintain engagement, a shortened version of the JSE was developed. This version includes 13 items—five reflecting cognitive empathy and 8 reflecting affective empathy—that were selected based on thematic clarity and their alignment with the measurement goals of the study. The item selection are shown in Appendix B, Table B.1.

3.5.2 Emotional Response (Positive and Negative Affect)

To better understand the emotional impact of the simulation, students are also asked to rate the intensity of their own emotions when thinking about people with schizophrenia. This part of the questionnaire is based on a validated French-language version of the Positive and Negative Affect Schedule (PANAS), adapted from Boiroux (2024) [5]. Participants rate each emotion on a 5-point scale (1 = "Pas du tout" to 5 = "Extrêmement").

The emotions included cover both positive and negative affective states such as:

Angoissé(e), Enthousiaste, Honteux(se), Inspiré(e), Intéressé(e), Irrité(e), Craintif(ve), Alerte, Attentif(ve), and Nerveux(se).

This allows for a more nuanced understanding of how the simulation influences students emotional reactions, which can be important in empathy development. The goal is not just to measure how much empathy increased, but also how the experience may have changed the emotional tone with which students think about individuals living with schizophrenia.

3.5.3 Perceptions of the Simulation

In addition to the JSE and the emotional response, participants which wore the headset, complete a short questionnaire immediately after the simulation, which evaluates their perceptions of the experience. This includes five statements rated on a 7-point Likert scale (1 = "Strongly disagree" to 7 = "Strongly agree"). The items are designed to assess how educational, immersive, and useful the simulation was perceived to be, as well as its potential to increase understanding and empathy. Example items include: *translate to english (?)*

- *La simulation était éducative.*
- *La simulation est un moyen efficace de sensibiliser à la schizophrénie.*
- *La simulation devrait rendre les gens plus compréhensifs à l'égard des personnes atteintes de schizophrénie.*

This helps evaluate how participants interpreted the experience and whether they found it meaningful in a learning context.

Together, the combination of the JSE, perception ratings, emotional intensity scales, and optional qualitative feedback provides a well-rounded view of the simulation's effectiveness. This multi-method approach is designed to explore whether a brief MR simulation can positively affect both empathy and emotional understanding, while also providing insights into the simulation's usability and educational value.

3.6 Design Choices

This methodology is directly informed by insights and gaps highlighted in the state of the art:

- MR is used instead of VR to reduce overloading the senses while preserving immersion [14].
- Debriefing sessions are included to increase meaningful reflection and avoid stigma [2, 26].
- The simulation content draws on real patient narratives to ensure authenticity and relatability [34].
- A short simulation duration enhances feasibility and safety without compromising emotional impact [10].

In summary, this study adopts a structured and ethically responsible MR-based approach to schizophrenia education. The goal is to increase both *affective* and *cognitive* empathy in medical students by situating simulated symptoms in real-world contexts, framed by education and post-reflection. This approach addresses gaps in current VR-centric literature and showcases a rather new method for developing empathy capacity in healthcare students.

4
Implementation

This chapter explains how the simulation was designed to give users a realistic sense of what it might feel like to experience hallucinations, as reported by people living with schizophrenia. The goal was to make the experience both immersive and educational—helping users not only understand the symptoms, but also feel more empathy for those who live with them. The following sections describe how the auditory and visual elements were created, why they were chosen, and how they work together to simulate a gradual progression from subtle discomfort to more intense hallucinations.

4.1 Structure of the Simulation

The simulation was intentionally structured to create an increasingly immersive and unsettling experience that mirrors hallucinations commonly reported in schizophrenia. This design was informed by both clinical research on psychotic symptoms and educational approaches shown to foster empathy and reduce stigma among healthcare professionals.

The auditory hallucinations included in the simulation are modeled after established training tools like Patricia Deegan's "Hearing Voices" program, which has been shown to significantly enhance empathy in both students and clinicians [13]. Building on this model, the simulation presents a series of whispered voices and confrontational phrases. These sounds are introduced gradually and increase in emotional intensity over time, reflecting research that shows emotional engagement enhances learning and empathetic understanding [30].

In addition to auditory elements, the simulation incorporates visual hallucination features. These include colored spheres that appear unpredictably, spatial distortions using scattered dots, and a darkening of the visual field. These visual effects were inspired by clinical reports of hallucinations in schizophrenia, which often describe geometric patterns, flickering lights, and distorted or symbolic images [28, 31].

The overall structure is designed to simulate both subtle and intense hallucinatory experiences. Initial symptoms—such as whispers and darkness—represent the early stages of perceptual changes. As the simulation progresses, the intensity of both auditory and visual elements increases to reflect the overwhelming nature of more severe psychotic episodes. This progression helps users understand how hallucinations can escalate over time and provides insight into the lived experience of individuals with schizophrenia.

4.2 Implementation of the Simulation

The simulation was developed in the Unity game engine, which provided the real-time rendering and interaction environment needed for an immersive experience. However, the core logic of the simulation was implemented through a set of custom C# scripts, each responsible for specific components of the experience. The main control flow is managed by `Orchestrator.cs`, which coordinates the sequence and timing of both auditory and visual elements. Additional functionality is handled by supporting scripts: `SoundManager.cs` manages playback of hallucination voice samples; `DotManager.cs` handles the appearance and disappearance of visual noise elements; `ScreenDarkener.cs` progressively dims the field of view; `DynamicWaveDeformation.cs` introduces surface-level visual distortions; and `ObjectCollision.cs` detects user interactions with hallucinated elements.

To simulate visual anomalies like stains or darkened edges, a custom shader called `FadeEdgeShader.shader` was created with the assistance of ChatGPT. This shader added another layer of perceptual distortion, contributing to the visual hallucination experience.

4.2.1 Orchestration

At the heart of the system lies the `Orchestrator.cs` script. This script sequences the entire simulation, controlling when sounds play, visual hallucinations appear, and environmental effects occur. The timeline was structured using IEnumerator coroutines, allowing asynchronous timed execution of events, ensuring immersive pacing without overwhelming the user too early in the experience.

```
IEnumerator OrchestrationSequence()
{
    Debug.Log("Simulation started");
    yield return new WaitForSeconds(60f);
    PlayWhispers();
    // visual field is getting darker

    yield return new WaitForSeconds(5f);
    soundManager.PlaySound("1");
}
```

Listing 1: Orchestration Coroutine

Synchronization across components ensures the user is not overwhelmed with concurrently being stimulated. For example, whispers begin before visuals, allowing users to acclimate to auditory disturbances before confronting the more visual hallucinations. Those are also paced in relation to emotional escalation in the voice samples, building tension across the timeline. The orchestrator also manages the timing of the visual effects, ensuring that they are introduced at appropriate intervals to create a sense of progression. For example, the gradual darkening of the screen is timed to coincide with the introduction of more intense auditory hallucinations, creating a more immersive experience.

4.2.2 Auditory Hallucinations

The auditory effects in the system are handled by the `SoundManager.cs` script. Audio files are grouped by voice type, making it easy to play back different kinds of hallucination samples. The script for these confrontational phrases was carefully drafted to include a range of emotional tones, from accusing to confused. This variety was designed to evoke a spectrum of feelings in the user, from discomfort to fear. The voices were generated using ElevenLabs, a text-to-speech AI engine [9], which allowed for the creation of distinct emotional tones that would be difficult to achieve with traditional voice acting.

Figure 4.1: Diagram of the Orchestrator system showing the interaction between auditory, visual, and environmental components.

Moreover, their timing is matched with visual effects to create a more immersive and realistic experience of multisensory hallucinations.

Important to mention as well is the close collaboration with the *Haute école de santé Fribourg, HEdS-FR*, with whom the script was discussed with and the tone of the voices was improved upon multiple meetings and discussions we had. The team provided valuable feedback on the emotional tone and content of the voice samples, ensuring that they accurately reflected the experiences of individuals with schizophrenia.

4.2.3 Visual Hallucinations

The simulation includes several visual effects designed to represent different kinds of hallucinations, based on how people with schizophrenia have described their experiences. One effect, created using the `DynamicWaveDeformation.cs` script, makes the surfaces of objects appear to ripple and shift. This gives them a wavy, moving look that reflects how perception can feel distorted during hallucinations.

Another visual, controlled by `ScreenDarkener.cs`, slowly darkens the edges of the screen over time. This creates a tunnel vision effect, simulating the sense of the world closing in that some people report during intense episodes.

The `DotManager.cs` script creates random red and blue dots that float above the user. These are meant to show visual noise—unstructured, scattered visuals like the flickering lights or colored shapes that people often describe. In addition, the `Orchestrator.cs` script causes glowing spheres to appear and disappear around the user. These spheres are meant to represent sudden visual objects or presences that seem real for a short time, adding to the feeling of confusion or invasion of personal space.

All these visuals are based on research that groups hallucinations into simple effects like light flashes, geometric patterns, or more complex shapes and objects [28, 31]. The system is built to be flexible, so more visual effects can easily be added in future versions.

4.2.4 Interaction Logic

The interaction logic is primarily handled by the `ObjectCollision.cs` script. This script detects when the user touches one of the spheres and triggers a response. The interaction is designed to be intuitive and immediate, with the sphere changing color and stopping its sound loop upon contact. In addition, the script adds interactive audio that loops until the user physically interacts with an object. This mimics the frustrating and unpredictable nature of hallucinations, as often described by people experiencing psychosis.

4.3 Challenges During Implementation

Discuss the main challenges encountered during the simulation development and how they were overcome. Highlight important coding aspects where appropriate.

Despite careful planning, several significant challenges emerged during the development of the simulation:

4.3.1 Audio Loop Management

Initially, each interactive sphere instantiated its own sound playback. This led to multiple overlapping sound loops, significantly breaking immersion and user experience. The problem arose because the audio logic was not centralized — each sphere's ObjectCollision component independently triggered audio playback upon spawning.

To solve this issue, a shared audio management system was developed, which is a static AudioSource and coroutine created within ObjectCollision.cs. This means that only one looped sound source exists, and it is globally stopped when a user interacts with any sphere.

A key logic excerpt illustrating this centralization is:

```
if (sharedAudioSource == null)  sharedAudioSource = ...; coroutineHost
= this; repeatCoroutine = coroutineHost.StartCoroutine(RepeatAudio());
```

This ensures no duplicate sounds occur, even with multiple spheres present.

4.3.2 Hand Interaction and Finger Identification

A second major challenge was accurately detecting when a user touched a sphere. Initially, an additional *poke interaction* module was mistakenly integrated alongside Unity's built-in collision detection. This redundant system caused conflicting behavior and unpredictable touch responses. Upon deeper inspection, it was discovered that Unity's hand collision system already assigns specific identifiers to each fingertip collider, such as *HandIndex1* for the index finger. Reliable detection could therefore be implemented simply by checking the collision object's name during a collision event, rather than adding redundant interaction modules.

```
if (collision.gameObject.name.Contains("HandIndex1"))  ...
```

By removing unnecessary modules and using direct collision name checks, touch interactions became smooth and predictable, immediately changing the spheres color and stopping the looping sound.

4.3.3 Hardware-Related Sound Privacy

During preliminary testing, the built-in speakers of the Meta Quest 3 were found to be too loud, leaking audio to the entire room and affecting non-participant observers. To address this, PhoneLook bone-conduction headphones were integrated into the simulation setup. This had the advantage that the audio is transmitted privately to the participant without occluding ambient sounds. It also ensures immersive simulatin while respecting privacy and the testing environment.

4.3.4 Spatial Placement of Sound Sources

Another significant challenge was the spatial arrangement of audio sources within the 3D simulation environment. Initially, it was difficult to orient myself correctly in Unityss Scene View, making it unclear where the sounds would originate from relative to the user's position. Proper placement was essential to create a convincing spatial auditory experience, because sounds had to feel anchored in specific locations in the environment. As the user moved, the sounds needed to remain fixed in space, enhancing realism and immersion.

To solve this, I invested time to become familiar with Unity's camera controls and 3D scene navigation.Then, the sound sources were distributed strategically across different coordinates, ensuring that different hallucinated voices would come from distinct spatial directions.

An example of the 3D placement of the sound sources in the Unity scene is shown in Figure 4.2.

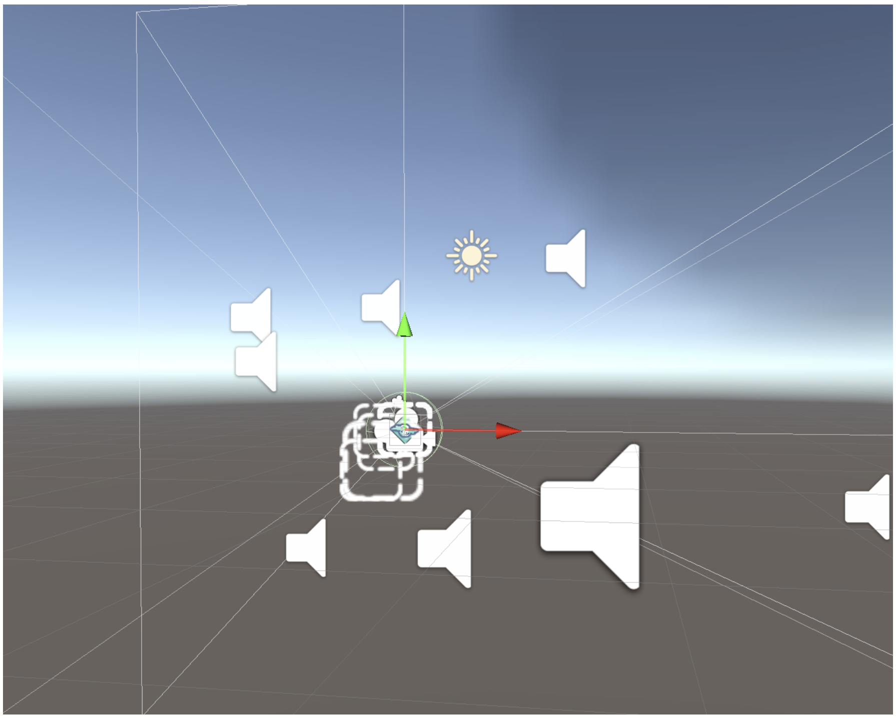

Figure 4.2: Placement of spatial sound sources in the Unity scene for the hallucination simulation. Each speaker icon represents a sound source emitting a hallucination voice.

5 User Study

In this section, you should present your user study and its methodology.

5.1 Methodology

6
Results and Analysis

In this section, you should present the results and their analysis. We recommend using graphics and charts to illustrate your result. Try to highlight the most important results.

7
Discussion

In this section, you should discuss your result and your work. Summarize and discuss your results, discuss your initial choices and compare with other works from the state of the art. How do you compare (if you can) ? Discuss your research questions in the light of your results.

8
Conclusion

This is a very important part of a report. Give all relevant conclusions, even negative. Stress novelty and scientific or industrial impact. Also new insights, outlook and recommendations for improvement should be put here. However, do not introduce results or concepts that belong in the body of the report. Bring structure in your conclusions.

A

JSE Items

Appendix A: JSE Items and Classification

JSE Item	Cognitive	Affective
1. My understanding of how my patients and their families feel does not influence medical or surgical treatment.		X
2. My patients feel better when I understand their feelings.		X
3. It is difficult for me to view things from my patients' perspectives.	X	
4. I consider understanding my patients' body language as important as verbal communication in caregiver-patient relationships.	X	
5. I have a good sense of humor that I think contributes to a better clinical outcome.	Ambiguous	Ambiguous
6. Because people are different, it is difficult for me to see things from my patients' perspectives.	X	
7. I try not to pay attention to my patients' emotions in history taking or in asking about their physical health.		X
8. Attentiveness to my patients' personal experience does not influence treatment outcomes.		X
9. I try to imagine myself in my patients' shoes when providing care to them.	X	
10. My patients value my understanding of their feelings which is therapeutic in its own right.		X
11. Patients' illnesses can be cured only by medical or surgical treatment; therefore, emotional ties to my patients do not have a significant influence on medical or surgical outcomes.	(X)	X
12. Asking patients about what is happening in their personal lives is unhelpful in understanding their physical complaints.	(X)	X
13. I try to understand what is going on in my patients' minds by paying attention to their non-verbal cues and body language.	X	
14. I believe that emotion has no place in the treatment of medical illness.		X
15. Empathy is a therapeutic skill without which success in treatment is limited.		X
16. An important component of the relationship with my patients is my understanding of their emotional status, as well as that of their families.		X
17. I try to think like my patients in order to render better care.	X	
18. I do not allow myself to be influenced by strong personal bonds between my patients and their family members.		X
19. I do not enjoy reading non-medical literature or the arts.	Ambiguous	Ambiguous
20. I believe that empathy is an important therapeutic factor in medical or surgical treatment.		X

Table A.1: Classification of JSE Items by Empathy Dimension (Cognitive vs. Affective)

B
Shortened JSE Item Set

Appendix B: Reduced Set of JSE Items and Classification

Selected JSE Item	**Cognitive**	**Affective**
2. My patients feel better when I understand their feelings.		X
3. It is difficult for me to view things from my patients' perspectives.	X	
6. Because people are different, it is difficult for me to see things from my patients' perspectives.	X	
7. I try not to pay attention to my patients' emotions in history taking or in asking about their physical health.		X
9. I try to imagine myself in my patients' shoes when providing care to them.	X	
10. My patients value my understanding of their feelings which is therapeutic in its own right.		X
12. Asking patients about what is happening in their personal lives is unhelpful in understanding their physical complaints.		X
13. I try to understand what is going on in my patients' minds by paying attention to their non-verbal cues and body language.	X	
14. I believe that emotion has no place in the treatment of medical illness.		X
15. Empathy is a therapeutic skill without which success in treatment is limited.		X
16. An important component of the relationship with my patients is my understanding of their emotional status, as well as that of their families.		X
17. I try to think like my patients in order to render better care.	X	
20. I believe that empathy is an important therapeutic factor in medical or surgical treatment.		X

Table B.1: Reduced JSE item set used in this study with classification into empathy components

C

Simulation Script (Original and Translation)

Français (Original)	**English (Translation)**
Écoute c'que dit l'enseignant	Listen to what the teacher says
Écoute attentivement.	Listen carefully.
Est-ce que t'entends ça ?	Do you hear that?
Tu connais la réponse ?	Do you know the answer?
Bien sûr que tu n'la connais pas	Of course you don't know it
T'es vraiment stupide.	You're really stupid.
Tu n'sers à rien	You're useless
Tu vois les autres ?	Do you see the others?
Ils parlent de toi.	They're talking about you.
Fais attention à toi.	Watch out.
Ne leur fais pas confiance.	Don't trust them.
Quelles sont ces taches ?	What are those stains?
Tu vois ça ?	Do you see that?
Concentre-toi !	Focus!
Les autres te regardent.	The others are watching you.
Tu n'le vois pas ?	You don't see it?
Regard vers le haut. Ya quelque chose !	Look up. There's something there!
Regarde maintenant !	Look now!
Qu'est-ce qui n'va pas chez toi ?	What's wrong with you?
Tu n'vaux rien	You're worthless
Touche les points !	Touch the dots!
Les autres veulent enregistrer tes pensées.	The others want to record your thoughts.
Tu dois faire attention !	You must be careful!
Regarde derrière toi !	Look behind you!
Regarde derrière toi !	Look behind you!
Fais attention !	Be careful!
Tu dois faire attention à toi !	You must look after yourself!

Table C.1: French simulation script with English translation

D
Supplementary Material

- Video Demonstration of the simulation can be found at: https://drive.google.com/file/d/1_U2-2wLRUy-T8k-vho5fKDLXekrJ9qi7/view?usp=drive_link.
- Github repository with code and simulation files: https://github.com/annkiener/mr-project.
- Consent form for the user study: https://drive.google.com/file/d/1S64vRfOto7NqJihL469CKGBPS9 view?usp=drive_link.
- Testing day protocol: https://docs.google.com/document/d/1Pfp2A3ZPfArS3Pdx0nXI2fMmpRA5js edit?usp=drive_link&ouid=110405891902671233690&rtpof=true&sd=true.
- Request to CEP committee: https://docs.google.com/document/d/1MIGT55N6jOy2Zi5T1ZnQ841Om2 edit?usp=drive_link&ouid=110405891902671233690&rtpof=true&sd=true.
- Questionnaires used in the study: .
- Participation form: https://drive.google.com/file/d/1-nNCUWIuby5HlzuaIRjFZk3ooMY_exzt/view?usp=drive_link

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Erklärung

gemäss Art. 28 Abs. 2 RSL 05

Name/Vorname: ....

Matrikelnummer: ....

Studiengang: ....

Bachelor ☐ Master ☐ Dissertation ☐

Titel der Arbeit: ....

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LeiterIn der Arbeit: ....

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Ort/Datum

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Unterschrift