MASTER IN COMPUTER SCIENCE

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

Master Thesis

Ann Kiener

University of Bern

supervised by
Prof. Elena Mugellini
Prof. Dennis Lalanne

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UNIVERSITÄT BERN

UNIVERSITÉ DE NEUCHÂTEL

UNIVERSITÉ DE FRIBOURG
UNIVERSITÄT FREIBURG

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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1
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) [30]. 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 [15, 28, 35].

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 [15]. These approaches have proven to be effective not only in increasing empathy and knowledge but also, in many cases, in reducing stigma among participants [13, 15].

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 [18, 34].

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) [18, 34].

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, 35]. 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 [29, 32]. 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 [18, 34]. 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 [9, 16].

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 [16].

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 [13].

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 [17].

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 [28]. 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 [28].

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 [28]. It also recommends combining simulations with brief educational sessions on schizophrenia to deepen understanding [28].

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 [31]. 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 [15]. 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 [15].

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 [15, 17, 28].

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, 23, 24]. 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 [20, 33]. 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, 24].

Understanding this and training empathy helps doctors and nurses better understand their patients and respond in helpful and compassionate ways [23, 24]. 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 [21, 24]. 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, 21]. 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 [12]. 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 [22]. 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 [11, 19, 21]. 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 [11]. 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 [14]. 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 [14].

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 [35].

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 [15, 28].

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 [20]. 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 [27]. 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 [21]. 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 [24]. 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 [27]. 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 [19].

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 [14, 35].

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, 35].

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 [35]. 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, 27].

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 [35].

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 [27].

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 3-4 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 [20, 33].
- MR remains underexplored, yet early studies suggest it can balance immersion and realism, potentially supporting more empathetic outcomes [15, 28].
- 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, 27].

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 [35].

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 [15]. 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 [20, 27].

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 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 3 to 4 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. At some point 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.

[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/`

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 [27, 35].

3.4 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 [15].
- Debriefing sessions are included to increase meaningful reflection and avoid stigma [2, 27].
- The simulation content draws on real patient narratives to ensure authenticity and relatability [35].
- A short simulation duration enhances feasibility and safety without compromising emotional impact [11].

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.

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.

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 what challenges arose during implemetation.

4.1 Structure of the Simulation

The simulation was intentionally structured to create an increasingly 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 [14]. 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 [31].

In addition to auditory elements, the simulation incorporates visual hallucination features. These include colored dots that appear, spatial distortions like dark stains, and a darkening of the visual field. These visual effects were inspired by clinical reports of hallucinations in schizophrenia, which often describe geometric patterns and distorted or symbolic images [29, 32].

The overall structure is designed to simulate both subtle and intense hallucinatory experiences. Initial symptoms—such as whispers and the darkening of the visual field—represent the early stages of 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.

Note: Include the sequence of the simulation here?

4.2 Implementation of the Simulation

Before diving into the details of how individual components work, it is helpful to understand how the entire simulation is structured and coordinated. 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 system is made up of several different scripts that control what the user sees and hears—from floating dots and stains to whispering voices. To make the experience feel immersive and believable, all of these effects need to happen at the right time and in the right order. This is where the central orchestrator comes in. The following sections explain how the simulation is timed and controlled, starting with the main orchestration logic that acts as the controller of the 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 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. The following diagram 4.1 illustrates the high-level structure of this system and the flow of variable dependencies among its components.

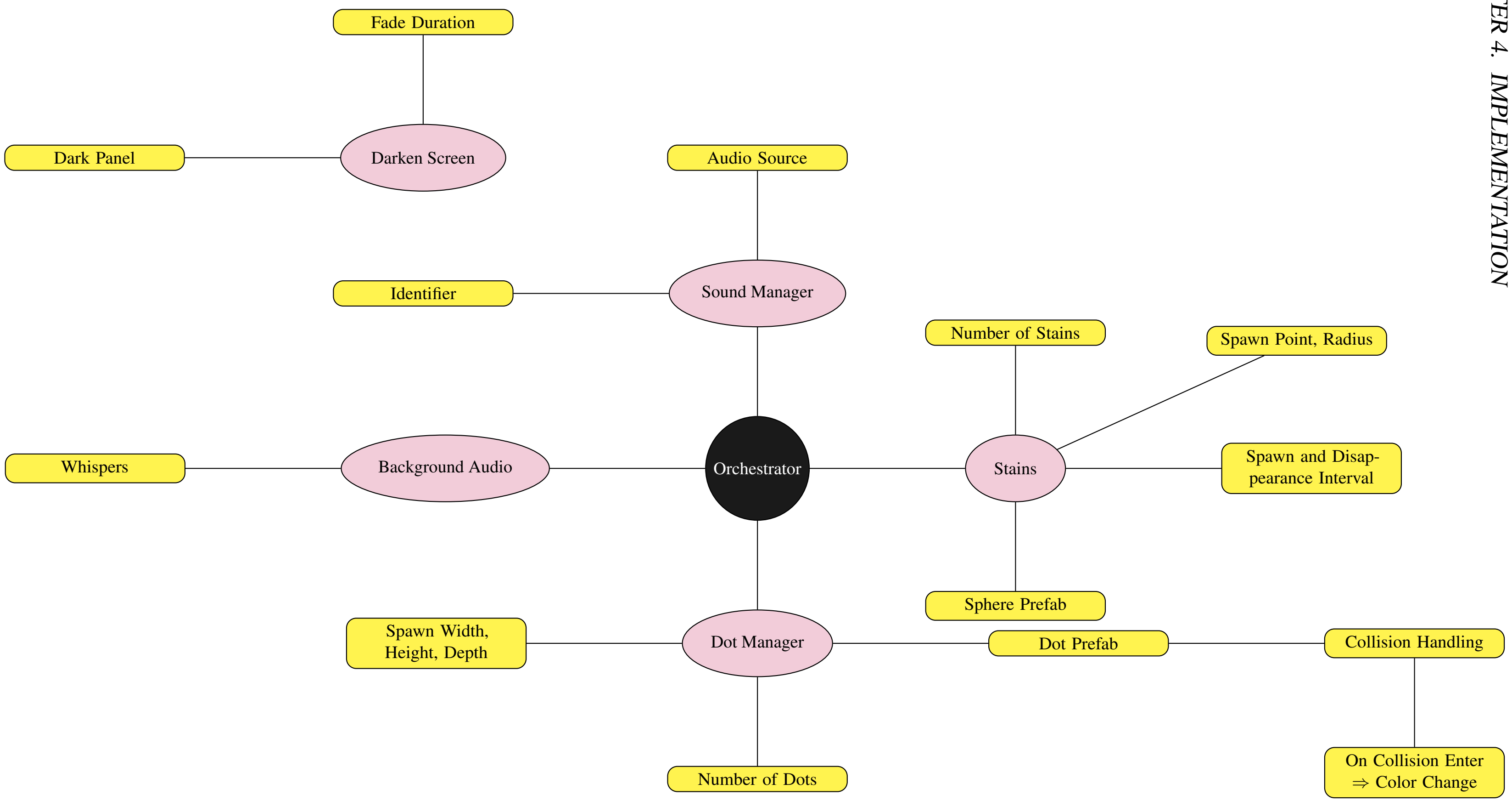

Figure 4.1: System architecture and variable orchestration for MR schizophrenia simulation.

4.2.2 Auditory Hallucinations

Auditory hallucinations in the simulation are managed by the `SoundManager.cs` script, which handles the playback of voice samples that simulate inner voices or intrusive thoughts. These sounds are intended to create an immersive and unsettling auditory environment that reflects commonly reported auditory hallucination experiences.

The core logic of the script is based on a list of `AudioSourceConfig` objects, each of which includes an `AudioSource` and a corresponding string identifier called `voiceGroup`. This was initially thought to be the identifier per voice, but as it became apparant that the script needs to follow a certain sequence, the identifier was stricly for knowing which section to play. Therefore, the script was divided into 12 parts, such that it could be controlled which part of the script should be played when.

Upon initialization, the script constructs a mapping of each voice group identifier to its respective audio source. When the method `PlaySound(string voiceGroup)` is called, the corresponding audio source is checked to ensure it is not already playing—this prevents overlapping audio playback. If no sound is currently playing for that identifier, the audio clip is played and logged for debugging purposes. If the requested identifier is not found, an error is reported.

The actual audio content was carefully scripted to reflect a broad emotional spectrum, ranging from ambiguous or confused statements to more aggressive or paranoid lines. These phrases were written in French—the working language of the institution—and designed to evoke discomfort and mostly distraction. To achieve a very natural tone of the voices, the voices were generated using the ElevenLabs text-to-speech AI platform [10], where voices can be created with specific promps. The prompts therefore instructed the AI platform to create a voice which was primarly scared, one which was whispering, and one which was more aggressive. The goal was to create a range of voices that could be used to simulate different types of auditory hallucinations, from soft whispers to more confrontational tones.

The voice samples were not developed in isolation. Their emotional tone, content, and perceived realism were refined through close collaboration with the *Haute école de santé Fribourg* (HEdS-FR). We reviewed the script with faculty members experienced in mental health care. Their feedback directly influenced the final selection of voice lines, ensuring that the content remained as truthful as possible.

The final script used in the simulation is shown in Table 4.1, presented in both the original French and their English translations.

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!
Fais attention !	Be careful!
Tu dois faire attention à toi !	You must look after yourself!

Table 4.1: French simulation script with English translation

To further enhance immersion, the timing of the voice playback is synchronized with corresponding visual effects, such as the appearance of stains or the darkening of the screen. This multisensory coordination aims to simulate the overwhelming and often unpredictable nature of psychotic episodes. The flexible structure of the `SoundManager.cs` makes it possible to easily add, remove, or sequence new voices for future versions of the simulation.

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.

4.2.3.1 Screen Darkening

The screen darkening effect in the simulation is implemented via the `ScreenDarkener.cs` component, which gradually overlays a semi-transparent black panel onto the user's visual field. This visual modification simulates a sense of tunnel vision or visual deterioration, contributing to the immersive experience of altered perception.

Technically, the effect is realized through a full-screen `Image` component referred to as `darkPanel`. This panel is a background panel from Unity itself with the color set to black. We can nicely see the panel in the Unity scene in figure 4.2.

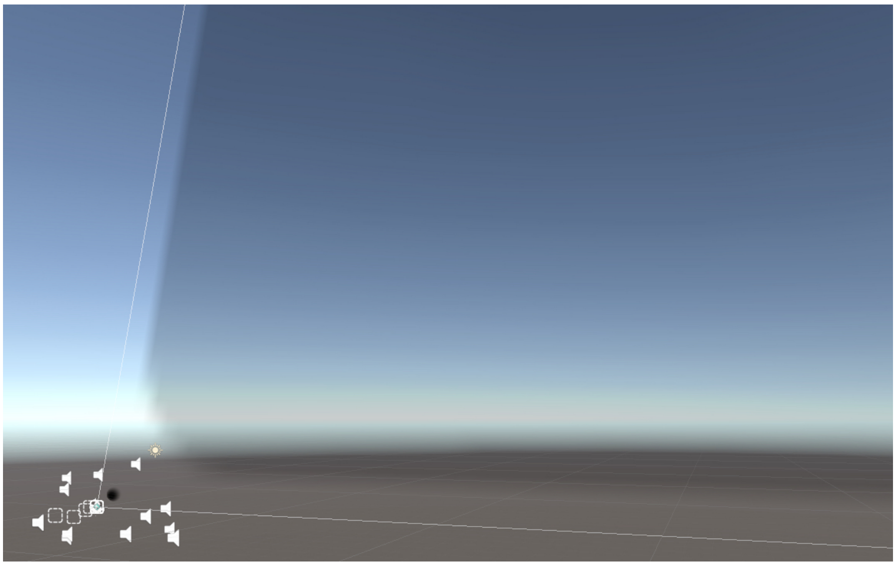

Figure 4.2: Dark background panel to mimic darkening of the user's visual field

At the start of the simulation, the alpha value of this panel is set to zero, ensuring that the screen appears completely transparent and preventing any initial visual flash. With the start of the simulation a coroutine is triggered that increases the panel's alpha value from 0 to 0.7 over a duration which can be set in Unity itself, called the (`fadeDuration`, typically 2 seconds).

The darkening culminates in a panel opacity of 70% (i.e., `alpha = 0.7`), which darkens the screen significantly without making it fully dark. This design choice maintains visibility while still inducing a sense of discomfort or visual strain. As such, the effect models subtle visual hallucinations or perceptual narrowing, which are commonly reported in psychotic experiences.

4.2.3.2 Stains

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. This deformation was applied to spheres which are triggered by a predefined spawn and disappearance interval. The spheres are randomly placed in the user's field of view, and they float around, creating a sense of visual noise. The `FadeEdgeShader.shader` shader was used to create a darkening effect around the edges of the screen, simulating the feeling of being in a confined space or having a limited field of vision. This shader was created with the help of ChatGPT, which provided a basic structure that was then customized to fit the specific needs of the simulation.

The `Orchestrator.cs` script manages when these spheres appear during the simulation timeline. The method `SpawnSphere()` is invoked repeatedly in a loop to instantiate the spheres at randomized positions around a central `spawnPoint`. The number of spheres and the interval between their appearances are determined by the parameters `sphereCount` and `spawnInterval`, respectively.Each sphere is placed within a circular area defined by a `spawnRadius`, with its Y-coordinate fixed to match the user's eye level for spatial consistency. After a fixed delay, the spheres are removed in the same order they appeared, one by one, using a queue-based removal mechanism and the `Destroy()` function.

The visual appearance of these spheres is designed to be ambiguous and somewhat unnatural. They show a constantly shifting surface that pulses and distorts as if they are made out of a wavy material to represent stains. This is achieved through the `DynamicWaveDeformation.cs` script, which displaces the vertices of each sphere's mesh in real time, to create this wave effect.

When oinstantiated, the script stores the original mesh vertices and continuously updates them every frame based on the wave function that combines sine and cosine operations on both the X and Z components of each vertex:

```
float wave = sin(time + x) * cos(time + z)
```

The wave value is multiplied by a configurable strength parameter called `waveAmplitude`, and this result is used to slightly move each point on the sphere's surface outward or inward along its normal direction. This creates a rippling effect across the whole object, making the sphere appear as if it is softly pulsing or ”breathing” while it exists in the environment.

Visual Example Figure 4.4 shows a black deforming sphere as it appears in the real-world mixed reality classroom context. The shader used for this object includes a soft fade around the edges, giving it a non-solid, ghostly appearance that blends slightly with the background. Figure 4.3 illustrates the same object in the Unity Editor, where the mesh deformation and alpha transparency are more clearly visible.

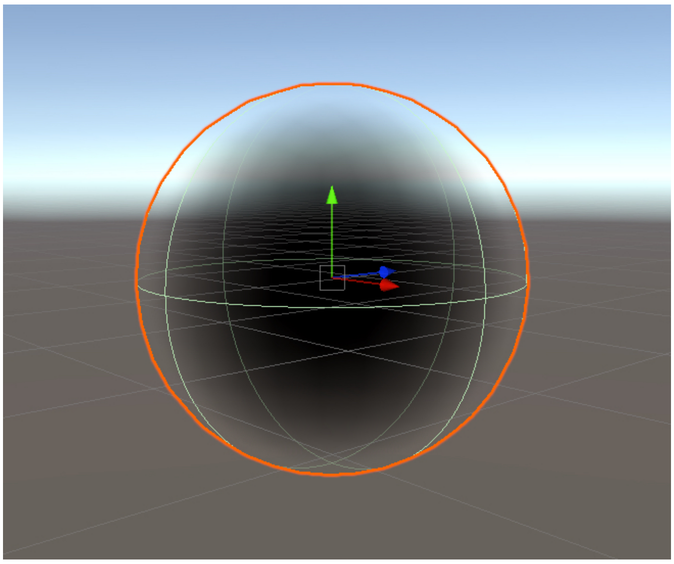

Figure 4.3: Example sphere with the `FadeEdgeShader.shader` and the `DynamicWaveDeformation.cs` script to mimic stains

4.2.3.3 Floating Dots and Interaction Logic

To help simulate the kind of perceptual disturbances that some people with psychosis experience, the simulation includes floating colored dots that the user can interact with. These are controlled by two main scripts: `DotManager.cs`, which creates the floating dots, and `ObjectCollision.cs`, which handles what happens when users touch the interactive spheres.

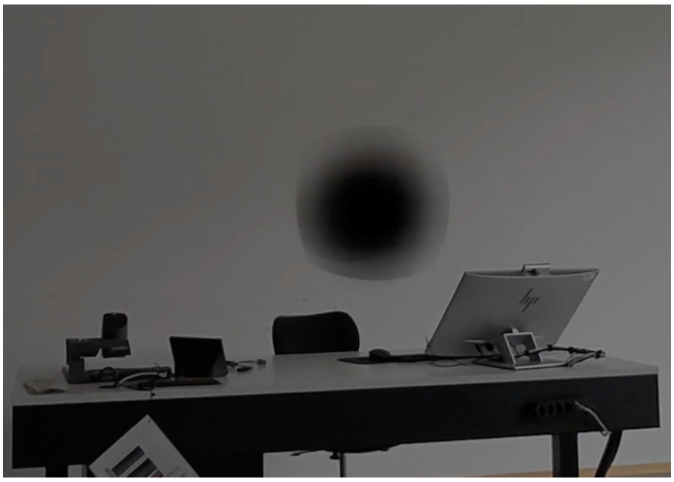

Figure 4.4: Stain appearing in the user's field of view

The `DotManager.cs` script is responsible for filling the space around the user with a number of small red and blue spheres—referred to as "dots." These dots are placed randomly within a area, defined by the parameters `spawnWidth`, `spawnHeight`, and `spawnDepth`. To not overcrowd the visual field, the script makes sure that each dot is placed far enough away from the others. If a dot would be too close to a previous one, a new position is chosen.

Each dot is randomly colored red or blue, creating a scattered, noisy effect. The idea is to make the environment feel just a bit off or overwhelming, without making it frightening.The dots are also meant to be more interactive. They appear at different moments in the simulation and are set up to respond when the user reaches out and touches them. The logic behind this is handled by the `ObjectCollision.cs` script.

Using Unity's collision detection system, the script monitors for `OnTriggerEnter` and `OnTriggerExit` events. When the user's hand (or other collider) enters the trigger zone of a sphere, the following actions are executed:

- The object's material is changed to a new, randomly generated color using `Random.ColorHSV()`. This signals to the user that the object has responded to their touch.
- The script searches the scene for an `AudioSource` tagged as `"Audio10"` and stops it using `audioSource.Stop()`. This source plays a looping sound *"Touche les points !"* (Touch the dots!), intended to mimic intrusive auditory hallucinations. Its termination represents a temporary sense of relief or control.

The interaction is simple but meaningful. It represents how some people try to manage or quiet their hallucinations—by focusing on them or interacting in some way. In the simulation, this also makes the experience more engaging and lets users take an active role, rather than just being passive observers.

Visual Example The images below illustrate the interaction process. In Figure 4.5, the user sees floating dots in their original red and blue state. After touching a sphere, as shown in Figure 4.6, the affected object changes color, confirming that the interaction was registered and the audio loop was interrupted.

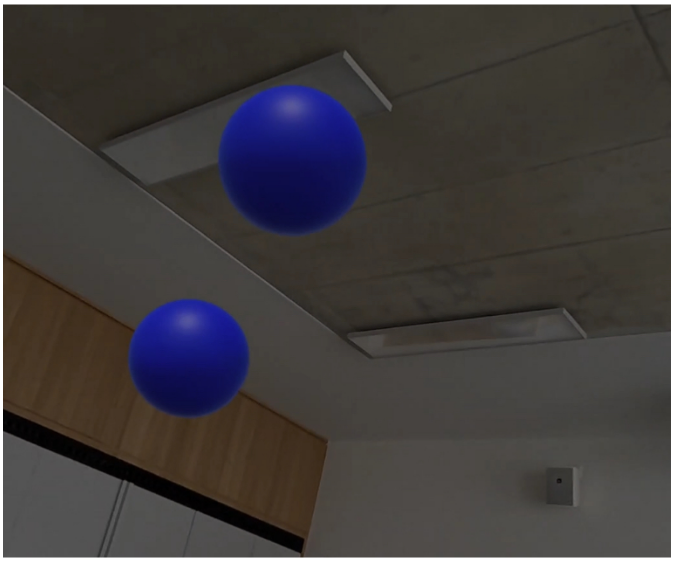

Figure 4.5: Floating dots before user interaction.

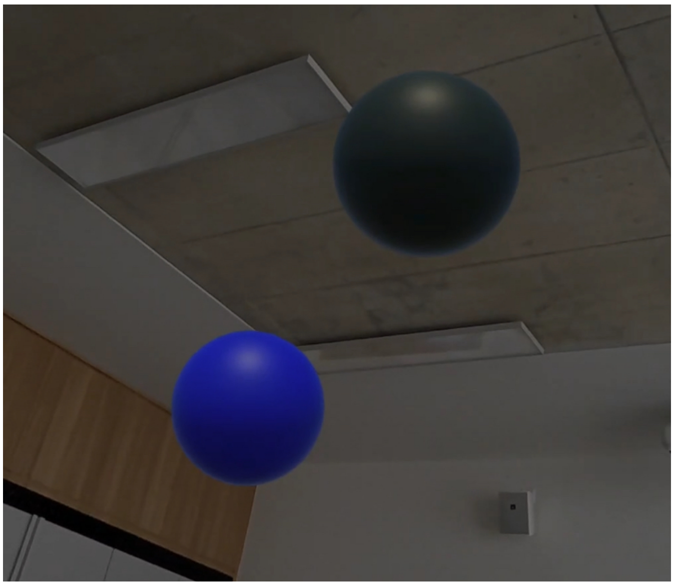

Figure 4.6: Color change after user touches one of the dots.

Together, these two systems—floating dots and interactive auditory element of the dots—form a approach to simulating environmental disruption. While the `DotManager.cs` creates persistent visual distraction, the `ObjectCollision` system adds intensity. The use of sound looping and the color change of the dots reinforces the themes of intrusion and momentary relief, central to the projects goal of eliciting empathetic insight into the lived experience of a psychosis.

4.3 Challenges During Implementation

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

4.3.1 Audio Loops

Initially, each interactive sphere instantiated its own sound playback. This led to multiple overlapping sound loops, which had to be fixed. The problem arose because the audio logic was not centralized — each sphere's ObjectCollision component independently triggered audio playback upon spawning. For example, if five spheres were instantiated, each would play its own sound, leading to overlapping audio. The audio would then only stop, if all five spheres were touched, which was not the intended behavior.

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 Finger Interaction

A second major challenge was accurately detecting when a user touched a dot. Initially, an additional *poke interaction* module was mistakenly integrated alongside the already built-in collision detection by Unity. This redundant system caused conflicting behavior and unpredictable touch responses. Upon deeper inspection, it was discovered that Unitys 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 implementing this and removing the redundant poke interaction, the color changing was a smooth process and the finger identification also worked.

4.3.3 Loud Audio

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 were being heard by observers. To address this, PhoneLook bone-conduction headphones[1] 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.

[1] `https://www.phonelook.ch/de/stylische-kabellose-bluetooth-knochenleitungs-kopfhorer-fur-sport-laufen-r` `html`

4.3.4 Spatial Placement of Audio

Another significant challenge was the spatial arrangement of audio sources within the 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 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 4.7.

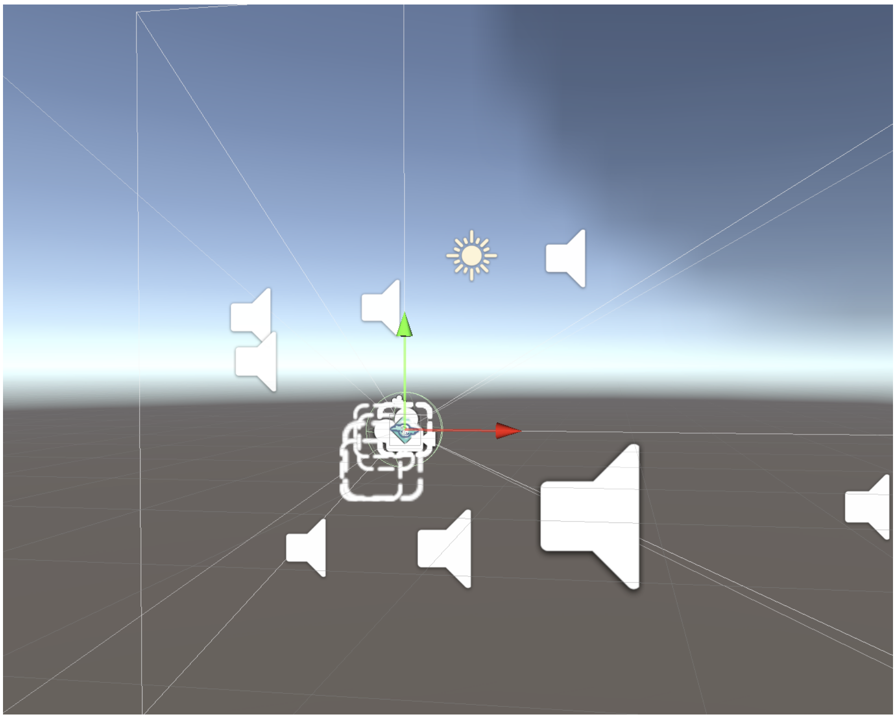

Figure 4.7: Placement of spatial sound sources in the Unity scene for the hallucination simulation. Each speaker icon represents a sound source emitting a hallucination voice.

5
User Study Design and Methodology

To systematically evaluate the educational and empathic impact of the MR simulation, a controlled user study was conducted with a total of 29 medical students enrolled at the Haute école de santé Fribourg (HEdS-FR). The study employed a pretest–posttest mixed-methods design, combining quantitative measures with group interaction and reflective feedback to understand the effects of the simulation experience.

5.1 Study Design Overview

The user study followed a three-phase structure: pre-simulation evaluation, simulation experience, and post-simulation evaluation. This structure allowed for a measurement of change in empathy and emotional response, and offered insight into both the direct effects of the MR simulation on the headset user and the indirect effects on observing students. The design aligns with educational best practices and recommendations in empathy training, particularly those emphasizing immersive realism combined with ethical framing and debriefing. The study was conducted in a controlled environment, with all participants receiving the same information and instructions. The simulation was designed to be brief yet impactful, allowing for a focused exploration of the experience of psychosis while minimizing potential distress. The study was approved by the HEdS-FR ethics committee, and all participants provided informed consent prior to their involvement. The study was conducted in accordance with ethical guidelines for research involving human subjects, particularly in the context of medical education and simulation.

The evaluation included both quantitative and qualitative components:

- **Pre-Evaluation:** Conducted immediately before the simulation, this questionnaire assessed participants prior experience with patients (especially those diagnosed with schizophrenia), and measured baseline empathy and emotional perceptions.
- **Post-Evaluation:** Completed directly after the simulation, this questionnaire repeated the empathy and emotion assessments and included additional questions about the participants experience with the simulation.

Two groups were compared in the post-evaluation: participants who engaged in the simulation as ”observers” (without the headset) and those who used the mixed-reality headset individually.

5.2 Participants

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 [14, 16].

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.

5.3 Procedure

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.

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) [12] 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 5.3.1.

The simulation itself lasts approximately 3 to 4 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.

5.3.1 JSE and B-PANAS Scales

The evaluation of the MR simulation's impact on empathy and emotional response is conducted using two primary measurement tools: the Jefferson Scale of Empathy (JSE) and the Brief Positive and Negative

Affect Schedule (B-PANAS). These tools are designed to capture both cognitive and affective dimensions of empathy, as well as emotional responses to individuals with schizophrenia.

5.3.1.1 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 [12]. 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.

5.3.1.2 Emotional Response (Positive and Negative Affect)

To better understand the emotional impact of the simulation, students were asked to rate the intensity of their own emotional responses when thinking specifically about individuals diagnosed with schizophrenia. This part of the questionnaire was adapted from a validated French-language version of the Positive and Negative Affect Schedule (PANAS), as published by Boiroux (2024) [5]. Participants rated each emotion on a 5-point Likert scale ranging from 1 ("Pas du tout" / "Not at all") to 5 ("Extrêmement" / "Extremely").

The selection of emotional terms was carefully curated to include an equal balance of five positive and five negative affective states. The goal of this design was to explore how the simulation might shift students' emotional associations with schizophrenia—either increasing compassionate or empathetic responses, or reducing feelings of fear, anxiety, or social discomfort. Rather than merely recording whether emotions intensified or weakened overall, the approach focused on identifying which specific emotional tones were affected and in what direction.

The following ten emotions were included in the questionnaire:

> *Angoissé(e) (Anxious), Enthousiaste (Enthusiastic), Honteux(se) (Ashamed), Inspiré(e) (Inspired), Intéressé(e) (Interested), Irrité(e) (Irritated), Craintif(ve) (Fearful), Alerte (Alert), Attentif(ve) (Attentive), and Nerveux(se) (Nervous).*

This set provides a balanced perspective on affective response. Positive terms such as *enthousiaste*, *inspiré(e)*, and *intéressé(e)* were selected to assess potential increases in empathy, engagement, and curiosity following the simulation. In contrast, negative emotions like *angoissé(e)*, *honteux(se)*, and *craintif(ve)* were included to evaluate whether the experience reduced discomfort, fear, or stigma-related reactions.

This measurement strategy supports a more nuanced understanding of how the MR simulation influenced the emotional lens through which students perceive individuals with schizophrenia. It complements the cognitive and affective empathy data from the JSE by offering insight into the emotional tone behind students' attitudes—an important factor in building compassionate clinical behavior.

5.3.2 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.*
  The simulation was educational.
- *La simulation est un moyen efficace de sensibiliser à la schizophrénie.*
  The simulation is an effective way to raise awareness about schizophrenia.
- *La simulation devrait rendre les gens plus compréhensifs à l'égard des personnes atteintes de schizophrénie.*
  The simulation should help people become more understanding toward individuals with schizophrenia.

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

5.3.3 Debriefing and Reflection

Following the simulation and post-questionnaire phase, all participants engaged in a structured debriefing session facilitated by a faculty moderator. This session provided a safe space for emotional and intellectual reflection. Participants were encouraged to share their thoughts, feelings, and interpretations of both the simulation and their observations. The discussion also addressed how the simulation might influence their attitudes or behaviors in future clinical interactions with patients diagnosed with schizophrenia.

5.4 Data Collection and Analysis

The data collected during the user study included both quantitative and qualitative components. Quantitative measures consisted of pre- and post-simulation scores on the JSE and B-PANAS for all participants, as well as Likert-scale responses to the post-simulation perception questionnaire completed by the headset user. These data were analyzed using within-subject comparisons, primarily through paired t-tests, to detect statistically significant changes in empathy and emotional affect. Differences between headset users and observers were also examined to explore how first-person versus observational engagement influenced outcomes.

Qualitative data were derived from transcripts of the debriefing sessions (with participant consent). These responses were analyzed using thematic coding to identify recurring motifs, such as emotional resonance, perceived realism, educational value, ethical reflections, and shifts in attitudes or understanding.

5.5 Ethical Considerations

Given the potentially distressing nature of psychosis simulation, the study was designed with multiple ethical elemnets. Participants received clear pre-study briefings and signed informed consent forms. The simulation was kept short in duration and grounded in a familiar environment to minimize psychological risk. The debriefing session served not only as a pedagogical tool but also as a psychological buffer, ensuring that students could process the experience in a safe, reflective manner. Participants were also reminded of their right to withdraw at any point without consequence.

6
Results and Analysis

This chapter presents the results of both the quantitative and qualitative analysis conducted to evaluate the impact of the mixed-reality simulation on participants' empathy and emotional responses toward individuals with schizophrenia. It begins with a breakdown of pre-evaluation findings that show baseline attitudes and empathy. Post-evaluation results are then presented, including changes in empathy and emotional states across the full sample, as well as subgroups (group participants and individual headset users). Statistical comparisons are used to assess whether observed differences are significant. Finally, we integrate observational and verbal feedback from participants to complement and contextualize the quantitative data. This mixed-methods approach allows for a richer understanding of the simulationss effects, particularly in areas not captured by standardized measures.

6.1 Pre-Evaluation Results

The pre-evaluation phase was conducted prior to any exposure to the simulation. It served to assess baseline levels of empathy and emotional responses toward individuals with schizophrenia. We also collected information on participants' experiences with patients and with that also patients with schizophrenia, which may influence their perceptions.

6.1.1 Experience with Patients and Schizophrenia

Participants were also asked about their prior experience working with patients in general and specifically with individuals diagnosed with schizophrenia. Responses were recorded on a 5-point scale ranging from 1 (No) to 5 (Yes).

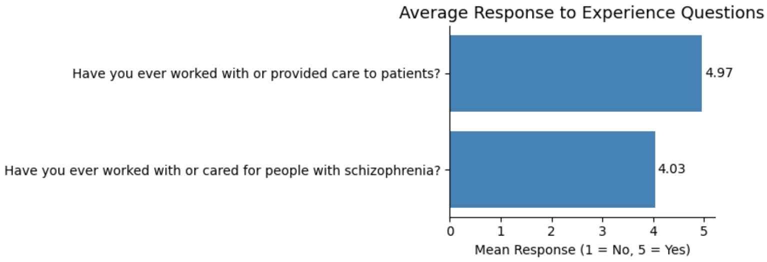

Figure 6.1: Answers to questions about experience with patients and schizophrenia.

As shown in Figure 6.1, nearly all participants reported prior experience working with or caring for patients, with an average response of 4.97. However, fewer had direct experience with individuals with schizophrenia, as indicated by a lower mean score of 4.03. This suggests a general familiarity with healthcare environments, but with that not as much exposure to psychiatric conditions.

6.1.2 Baseline Perceptions and Empathy

Participants responded to a set of 13 Likert-scale items evaluating cognitive and affective components of empathy. These items were scored from 1 (Strongly Disagree) to 6 (Strongly Agree), with reverse scoring applied to negatively phrased statements.

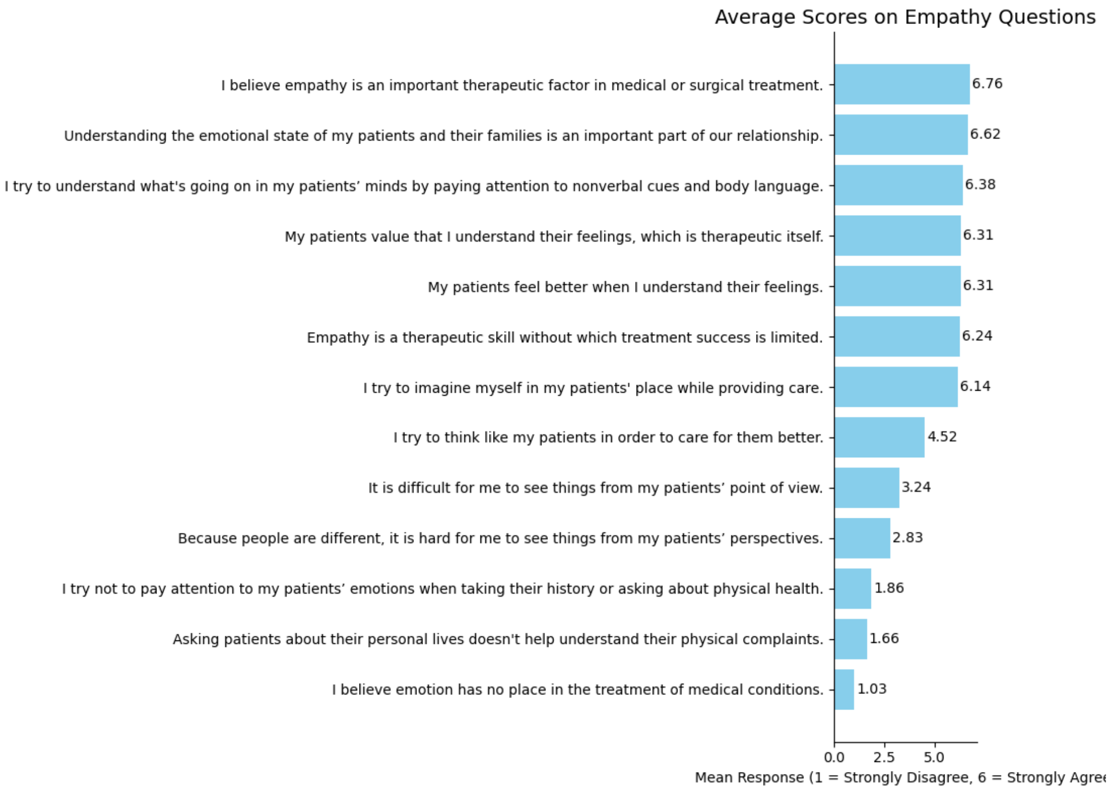

Figure 6.2: Average item-wise scores on empathy-related questions.

Figure 6.2 shows the average scores per item. Responses were generally high for positively phrased statements (e.g., “I believe empathy is an important therapeutic factor”), indicating strong baseline attitudes in favor of empathic engagement. In contrast, negatively phrased items (e.g., “I believe emotion has no place...”) received low agreement, as expected after reverse scoring.

To explore potential variation across groups, empathy scores were also averaged by the time at which participants completed the evaluation session. These groups were constructed based on session start times.

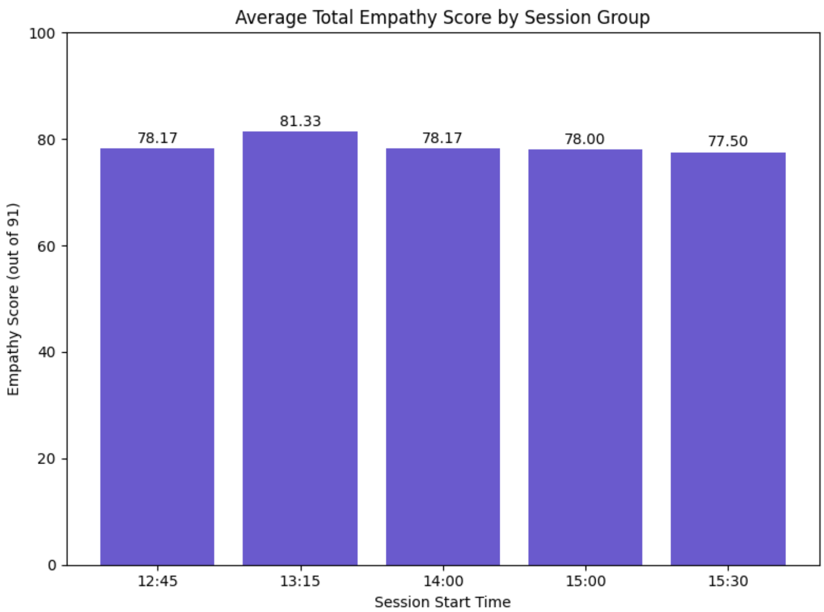

Figure 6.3: Average total empathy score by session start group.

As shown in Figure 6.3, total empathy scores were relatively consistent across session groups. The highest group average (81.33) was observed for the 13:15 session, though variation across all time slots remained modest (range: 77.50–81.33). This suggests time-of-day or group assignment had minimal influence on baseline empathy.

Participants also rated how strongly they associated various emotions with thinking about individuals with schizophrenia, on a scale from 1 (Not at all) to 5 (Extremely).

Figure 6.4 presents the average self-reported intensities for each emotion. “Attentive,” “Alert,” and “Interested” ranked highest, indicating cognitive engagement. Negative emotions such as “Ashamed” and “Irritated” were reported with relatively low intensity, suggesting a limited baseline presence of stigmatizing emotional responses.

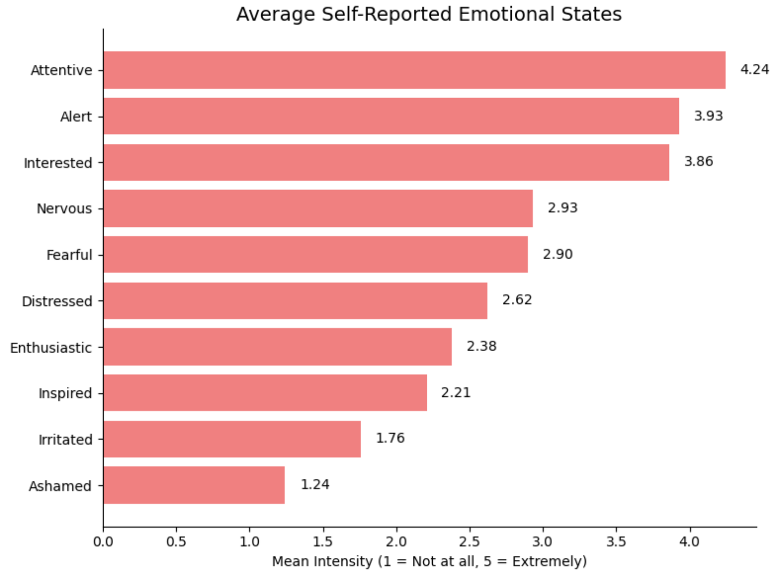

Figure 6.4: Average self-reported emotional intensity associated with thinking about people with schizophrenia.

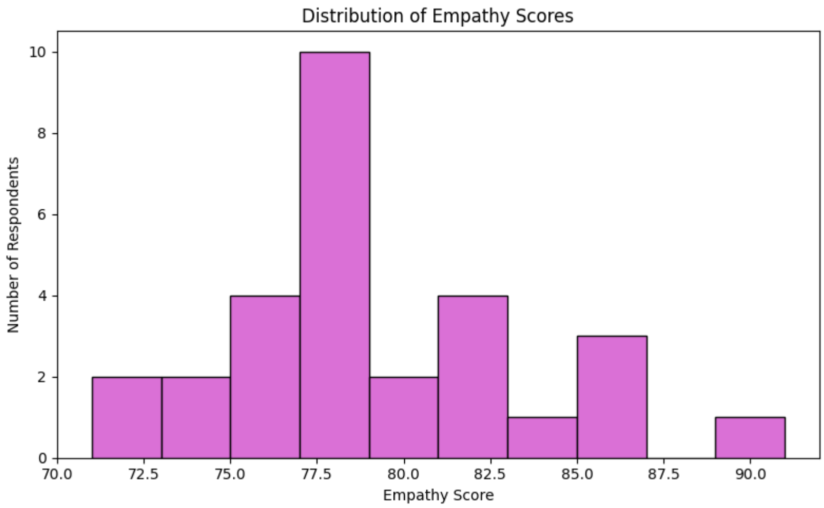

Figure 6.5: Distribution of total empathy scores among participants.

Finally, Figure 6.5 displays the distribution of total empathy scores. The majority of participants scored between 75 and 85 out of a maximum of 91, further confirming the high initial level of empathy among the sample.

These baseline findings establish that participants entered the intervention phase with generally high empathy and cognitive openness. This may present a ceiling effect, potentially limiting the observable shift in post-intervention scores.

6.2 Post-Evaluation Results

Following participation in the simulation, participants completed a post-evaluation survey that assessed both their emotional responses and empathy levels, which features the same question set as the pre-evaluation. These include the Jefferson Scale of Empathy (JSE) [12] 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. This section presents the results for the full sample as well as two subgroups: those who participated in a group setting and those who experienced the mixed-reality (MR) simulation individually using the headset.

Participants were asked to rate the intensity of various emotional states they experienced when thinking about individuals with schizophrenia. These ratings were provided on a 5-point scale ranging from 1 (Not at all) to 5 (Extremely).

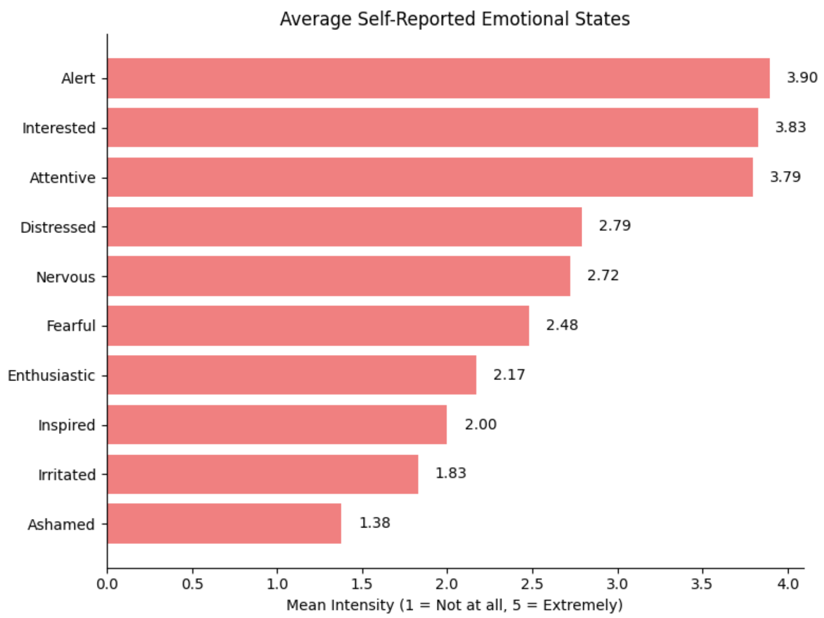

Figure 6.6: Average self-reported emotional states (all participants).

As shown in Figure 6.6, the most intense emotions reported across all participants were *Alert*, *Interested*, and *Attentive*, suggesting a heightened level of engagement and focus during or after the simulation. Emotions such as *Ashamed*, *Irritated*, and *Inspired* were rated much lower, indicating that negative or affectively charged responses were less commonly experienced.

6.2.1 Group Participants

Participants who took part in the simulation in a group setting (e.g., without MR headset) reported emotional responses that were broadly similar to the overall sample. However, their average emotional intensity was slightly higher on items related to awareness and cognitive involvement.

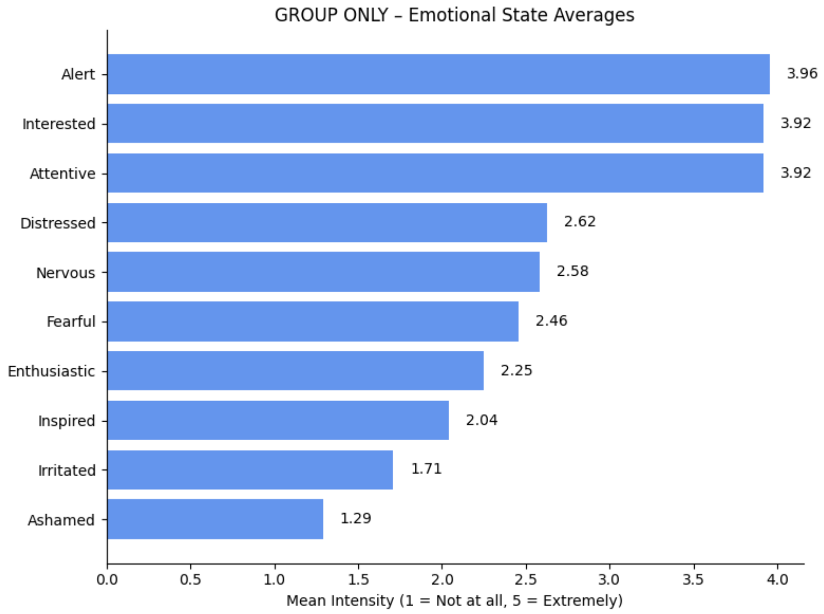

Figure 6.7: Average emotional state ratings – Group participants only.

As shown in Figure 6.7, *Alert*, *Interested*, and *Attentive* again appeared most strongly. The spread of emotional intensities was relatively consistent with the full group.

The distribution of their overall empathy scores is presented below.

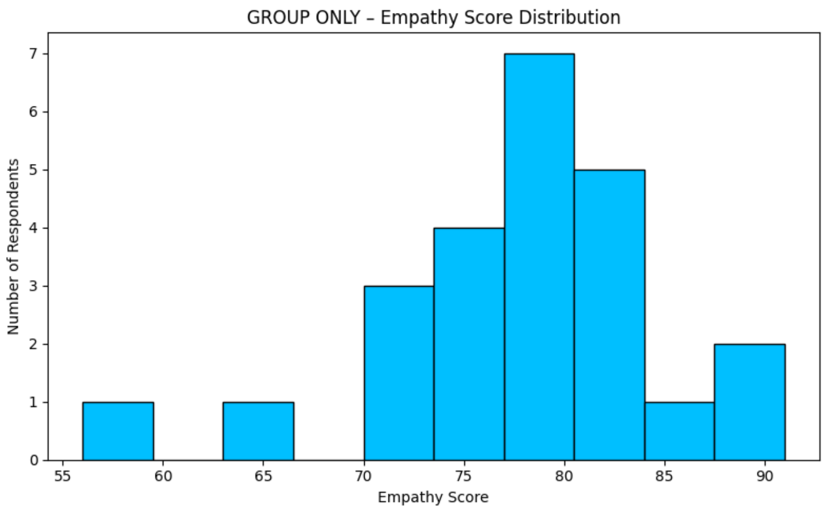

Figure 6.8: Empathy score distribution – Group participants only.

The majority of participants in the group condition scored between 75 and 85 on the empathy scale (max = 91), indicating high levels of empathy across the group.

6.2.2 Individual Participants – MR Headset Users

Participants who engaged with the MR simulation individually using the headset demonstrated slightly different patterns. Their emotional responses included relatively higher levels of *Distress* and *Nervousness*, suggesting a deeper affective impact.

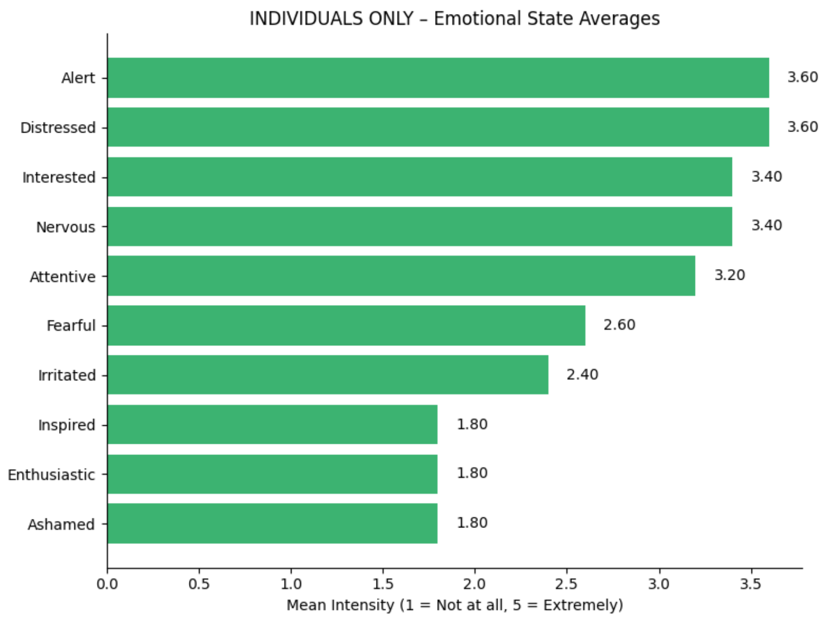

Figure 6.9: Average emotional state ratings – Individual (headset) participants.

While cognitive engagement emotions like *Alert* and *Interested* remained high, headset users also showed increased ratings for affective states such as *Distressed*, *Fearful*, and *Nervous*, suggesting that the immersive simulation may have elicited stronger emotional reactions.

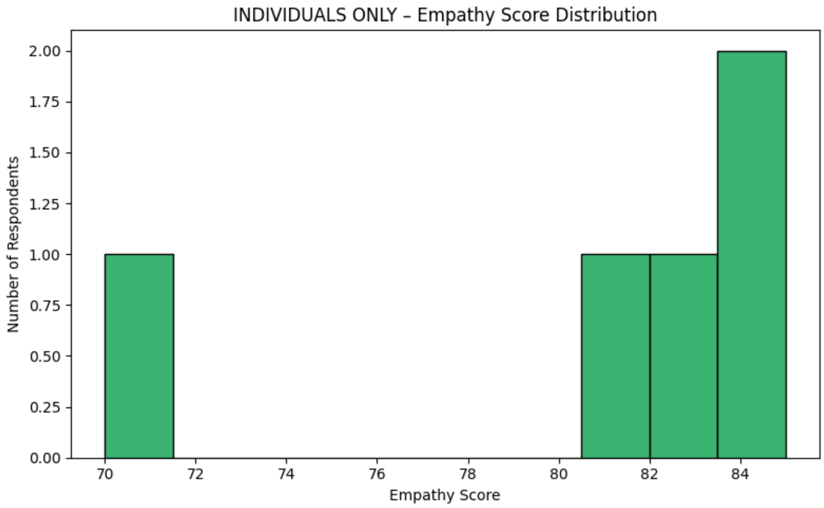

Figure 6.10: Empathy score distribution – Individual (headset) participants.

Empathy scores in this group were tightly clustered at the higher end of the scale, indicating that most headset users reported strong empathic attitudes following the simulation.

6.2.3 Overall Empathy Score Distribution

The full sample distribution of post-evaluation empathy scores is shown below. The majority of respondents scored between 75 and 85 out of 91, reflecting high baseline and post-intervention empathy.

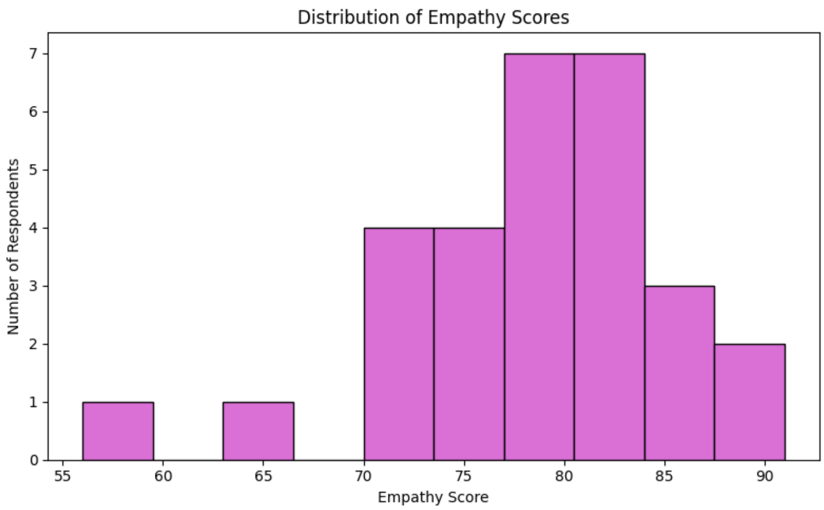

Figure 6.11: Empathy score distribution – All participants.

6.2.4 Simulation Evaluation Statements

Participants were also asked to rate their agreement with various statements evaluating the simulation experience. These were scored on a 7-point scale (1 = Strongly Disagree, 7 = Strongly Agree).

Figure 6.12: Average participant ratings of simulation statements.

Figure 6.12 shows near-universal agreement on the simulation's educational value, realism, and ability to foster understanding. The only statement that received strong disagreement was the suggestion that the simulation "should not be used by people who want to work with people with schizophrenia," reflecting strong perceived value and acceptability of the tool.

6.3 Pre vs. Post Comparison Analysis

This section presents a statistical comparison of participants' empathy and emotional responses before and after the simulation experience. By analyzing both group-level changes and individual-level changes, we evaluate whether the intervention led to measurable shifts in perspective or affect. Empathy scores, cognitive and affective, and emotion ratings were analyzed using methods suited for this data.

6.3.1 Score Matching and Methodology

Empathy scores were calculated based on 13 Likert-style attitude items, some of which were reverse-scored to account for negatively phrased statements. Each participant's total empathy score was the sum of their responses, yielding a possible range of 13 to 91 points.

To evaluate changes in emotional response and empathy after the intervention, we conducted paired comparisons between pre- and post-evaluation data. The primary statistical test which was employed for this is the **Wilcoxon Signed-Rank Test:** used to assess empathetic and emotion-related changes, due to the ordinal nature of Likert data and lack of distribution assumptions.

All tests were two-tailed with a significance threshold of $p < 0.05$. The Wilcoxon test was chosen over a paired t-test due to the non-normal distribution of the data. This approach is robust for small sample sizes and ordinal data [8].

The hypotheses for this test were defined as follows:

- **Null hypothesis (H_0):** There is no difference in median empathy scores between the pre- and post-evaluation.
- **Alternative hypothesis (H_1):** There is a difference in median empathy scores between the pre- and post-evaluation.

6.3.2 Statistical Test Results

To assess the impact of the intervention, we applied statistical tests to compare pre- and post-evaluation responses. These analyses focused on total empathy scores, cognitive and affective empathy subscores, and emotion ratings, with significance evaluated at $p < 0.05$.

6.3.2.1 Empathy Score Comparison

We compared pre- and post-evaluation empathy scores using a Wilcoxon signed-rank test to assess the effect of the intervention.

- **Mean (Pre-Evaluation):** 78.66
- **Mean (Post-Evaluation):** 78.28
- **Wilcoxon test:** $W = 186.0,\ p = 0.7723$

While the mean empathy score decreased slightly from pre to post evaluation, the difference was not statistically significant based on either test. The Wilcoxon test returned a p-value of 0.7723, which is well above the common significance threshold of $\alpha = 0.05$. Therefore, we fail to reject the null hypothesis. While the mean empathy score decreased slightly from pre to post evaluation, the difference was not statistically significant. This suggests that the intervention may not have produced a measurable change in empathy, or that individual effects varied too widely for an overall trend to emerge.

Metric	Pre	Post
Mean Score	78.66	78.28
Standard Deviation	4.44	7.07

To further explore the effect of the intervention on participant empathy, we examined both the distribution of empathy scores and individual-level changes from pre- to post-evaluation.

Figure 6.13 shows the histogram of empathy scores from the pre- and post-evaluation phases. The distributions are visually similar, with most scores falling between 70 and 85. The post-evaluation scores exhibit slightly more variability, including a small number of lower scores. However, there is also a subtle rightward shift in the upper end, indicating some participants may have increased their scores. Overall, no major distributional shift is apparent.

In Figure 6.14, each dot represents a participant's empathy score before and after the intervention. Red diamonds indicate the group means, and the dashed red line connects the mean pre- and post-scores.

This visualization confirms that although the individual scores are distributed across a similar range, the group mean remained effectively stable. A few participants show noticeable changes in either direction, but the majority maintained consistent empathy scores. The mean dropped slightly from 78.66 (pre) to 78.28 (post), as also reflected in the results of the Wilcoxon signed-rank test ($p = 0.7723$). This supports the interpretation that the intervention did not result in a statistically significant change in overall empathy levels.

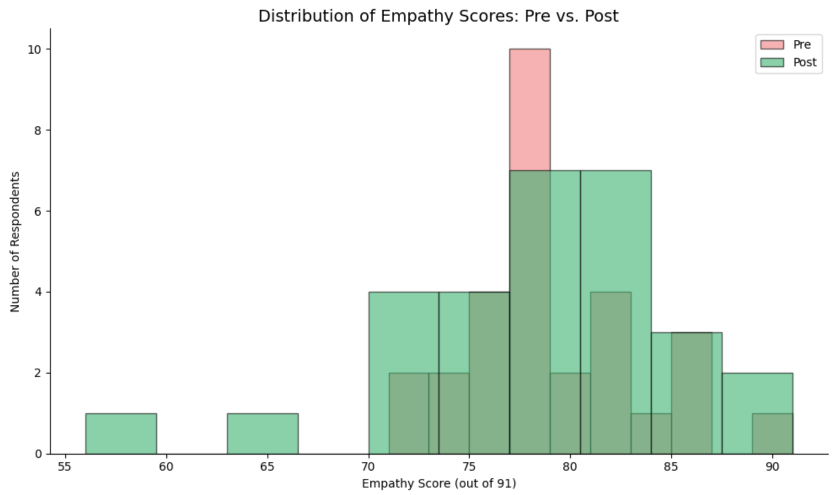

Figure 6.13: Distribution of Empathy Scores Before and After the simulation.

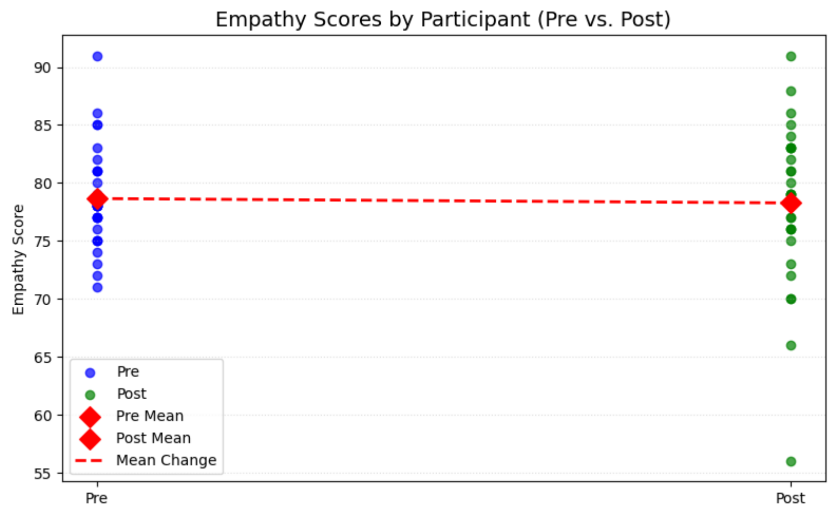

Figure 6.14: Empathy Scores by Participant: Pre vs. Post with Mean Comparison.

These graphs underscore the importance of looking beyond averages: while the group-level effect was minimal, some individuals experienced increases or decreases that could be explored further—especially through qualitative methods or subgroup analysis.

To explore possible group-level effects, we compared average empathy scores by session group. This analysis was motivated by observations made during the simulation sessions: in some groups, the participant using the headset exhibited noticeable engagement — through verbal reactions, physical responses, or expressions of immersion — while in others, the headset user remained relatively passive. Given that the design of the simulation aimed to stimulate empathy through this shared experience, we hypothesized that such variability in engagement might influence group-level outcomes.

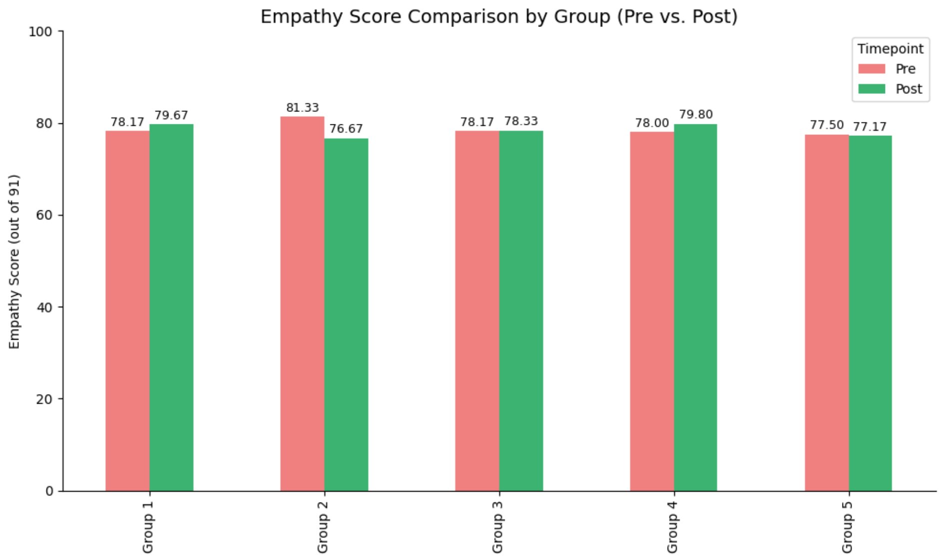

Figure 6.15: Empathy Score Comparison by Group (Pre vs. Post).

Figure 6.15 illustrates mean empathy scores for each group before and after the intervention. The scores remain remarkably stable across all groups, with small increases observed in Groups 1, 3, and 4, and small decreases in Groups 2 and 5. None of these differences were large enough to suggest a meaningful group-specific effect. This reinforces the previous conclusion that the intervention did not produce a systematic shift in overall empathy scores.

To better understand the nature of the empathy being measured, we also decomposed the total score into two subcomponents: *cognitive empathy*, which reflects perspective-taking and understanding mental states; and *affective empathy*, which involves emotional resonance and compassion.

As shown in Figure 6.16, there was almost no change in either subscore. The average cognitive empathy score dropped minimally from 26.97 to 26.69, while the affective empathy score showed an equally small decrease from 51.69 to 51.59. These results suggest that neither cognitive nor affective dimensions of empathy were meaningfully altered by the simulation experience.

Together with the individual, group, and total score analyses, this subscale breakdown adds further support to the interpretation that the intervention had limited impact on participants' self-reported empathy levels — at least as measured immediately after the experience.

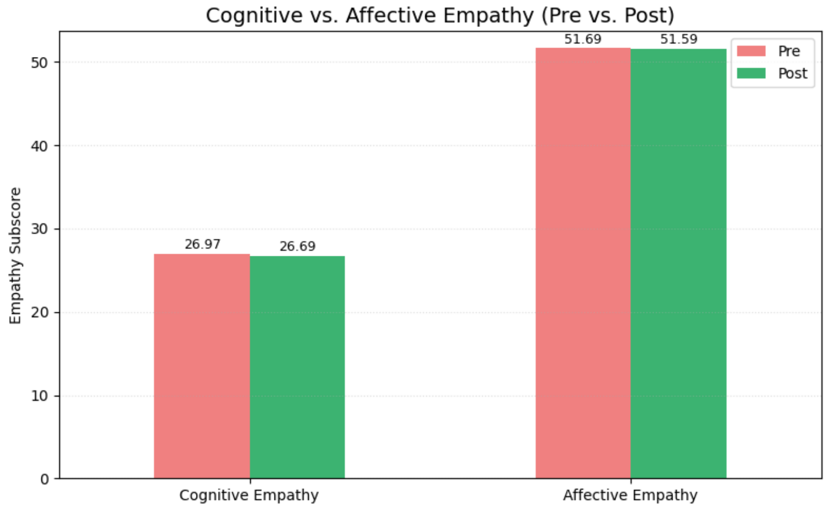

Figure 6.16: Cognitive vs. Affective Empathy Scores (Pre vs. Post).

6.3.2.2 Emotional Response Comparison

To explore whether participants' emotional responses toward people with schizophrenia changed following the simulation, we conducted a series of Wilcoxon signed-rank tests—one for each of the ten emotion items reported pre- and post-intervention.

Hypotheses. For each emotion, the test was conducted under the following hypotheses:

- **Null Hypothesis (H_0):** There is no median difference in emotional intensity pre- and post-simulation; i.e., the simulation did not affect how strongly participants felt the emotion.
- **Alternative Hypothesis (H_1):** There is a median difference in emotional intensity between pre- and post-simulation responses.

Table 6.1: Wilcoxon Signed-Rank Test Results for Emotion Changes

Emotion	Pre Mean	Post Mean	W-statistic	p-value	Significant
Attentive	4.241	3.793	72.0	0.0633	False
Fearful	2.897	2.483	77.0	0.1739	False
Ashamed	1.241	1.379	14.5	0.3302	False
Enthusiastic	2.379	2.172	97.5	0.3353	False
Nervous	2.931	2.724	86.0	0.4702	False
Inspired	2.207	2.000	48.0	0.4903	False
Distressed	2.621	2.793	108.0	0.5387	False
Irritated	1.759	1.828	47.5	0.7483	False
Interested	3.862	3.828	89.5	0.8190	False
Alert	3.931	3.897	150.0	1.0000	False

None of the tested emotions showed a statistically significant difference between the pre- and post-evaluations at the $p < 0.05$ threshold. The emotion *Attentive* approached significance ($p = 0.0633$), suggesting a possible decrease in attentiveness after the simulation, but this trend did not reach statistical reliability.

To visualize the direction and relative magnitude of changes, the figure below shows the average change in each emotion (post minus pre). Positive values indicate increased emotional intensity post-simulation.

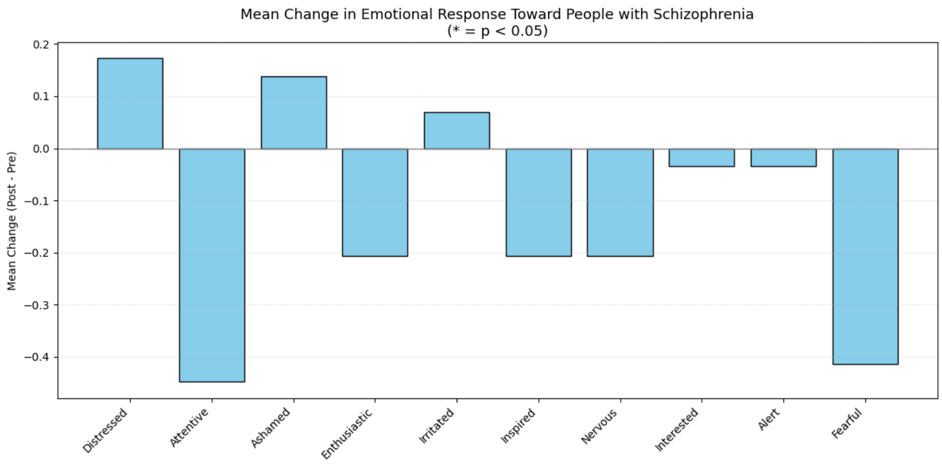

Figure 6.17: Mean change in emotional response toward individuals with schizophrenia. (* = $p < 0.05$)

While no statistically significant changes were found, the figure illustrates trends in participants' emotional shifts. Notably, small increases were observed for emotions like *Distressed*, *Ashamed*, and *Irritated*, whereas emotions such as *Fearful*, *Alert*, and *Attentive* showed modest decreases.

These results suggest that while the simulation may have had subjective effects on emotional perception, the changes were neither strong nor consistent enough to yield significant results across the group. Further qualitative analysis or larger samples may help better characterize individual emotional impacts.

6.4 Mixed Methods Integration

In addition to statistical analyses, observational and self-reported qualitative data were collected to complement the quantitative findings. This included behavioral observations during the MR experience, informal comments post-session, and open-ended feedback where available.

Participants who wore the MR headset shared reflections that contextualized their Likert-scale responses. These insights helped explain individual variability and added depth to our understanding of the simulations emotional impact.

6.4.1 Participant Experience and Observational Feedback

During each session, one participant wore the MR headset simulating auditory and visual hallucinations while attempting to complete a simple task. The rest of the group observed and participated in the same task under normal conditions. This design aimed to allow both the headset user to experience symptoms first-hand and the group to witness their visible effects, ideally fostering empathy through both perspectives.

Notable behavioral patterns varied across participants. Some headset users displayed visible signs of discomfort, such as pinching their lips, turning their heads, hesitating, or seeking clarification. Others remained largely focused on the task, displaying minimal reaction to the simulation.

Group reactions also varied: in some cases, there were uneasy chuckles, concerned glances, or verbal encouragements ("be brave," "do you need help?"). In other groups, external participants were largely unaware of the internal struggle the headset user was experiencing—sometimes forgetting the headset was even present.

Table 6.2: Summary of Headset User Experience and Group Reactions

Group	Headset User Behavior	Group Reaction	Key Participant Quotes
Group 1	Nervous laughter, looked around, avoided interacting with virtual elements, reported confusion.	Limited group reaction; one participant quietly offered encouragement.	"The voices keep pulling you down." "It's persecution." "I now understand my cousin better."
Group 2	Initially unreactive, later visibly overwhelmed, touched spheres, slight disorientation.	Mild group curiosity, one noted concern, most forgot headset was active.	"There was too much information." "I forgot the instructions." "It's harder not to do what the voices say."
Group 3	Visibly uncomfortable, delayed task start, repeated lip-pinching, eventually emotional.	Group unaware during task, visibly moved after, discussion emerged post-experience.	"It was horrible." "I couldn't concentrate... even now I don't know." "If 2 minutes is absorbing, I can't imagine the people who feel that way every day."
Group 4	Focused externally, but no interaction with visual stimuli. Seemed shocked post-experience.	Participant's distress was internalized; group noticed little during the task. Two members heard audio leaks.	"The voices were disturbing." "Living the symptoms is another level of experience." "I think I have more empathy now."
Group 5	Started quickly but showed signs of discomfort; pinched lips and waited impatiently for the end.	Group was mostly unaware of the participant's inner struggle.	"It took a lot of energy and concentration." "The longer it took, the more frightening it became." "The simulation helped me realize what they go through."

6.4.1.1 Verbal Feedback from Participants

Several headset users described strong emotional and cognitive impacts during the debrief. Themes included difficulty concentrating, feeling overwhelmed, dissonance between task instructions and intrusive voices, and a greater understanding of what people with schizophrenia might endure. Some illustrative quotes include:

- "We try to focus on something good but the voices keep pulling you down."
- "At first I really didn't want to listen to the voices, but then I couldn't… It's harder not to do what the voices say."
- "I couldn't understand the instructions… even now I don't know what we were supposed to do."
- "It was horrible. The voices made simple tasks feel impossible."
- "It was emotionally sad… I didn't want to look up because I was scared of what I'd see."

- “It took a lot of concentration… I was glad when it was over.”
- “I remember my cousin has schizophrenia… now I feel like I better understand what he feels.”

Observers also shared reflections:

- “I forgot she was wearing the headset… then I saw her moving strangely and I got worried.”
- “Seeing her struggle was emotional. It changed how I think about people with schizophrenia.”
- “She didn’t react much, so I didn’t realize it was hard for her.”

6.4.1.2 Interpretation and Reflection

The qualitative data collected from the debriefs offer valuable insights that contextualize the lack of statistically significant changes in empathy scores. While numeric measures showed minimal change, many participants described deep emotional and cognitive disruption during the simulation, often in ways that are not easily quantifiable.

A consistent theme was the intensity of auditory hallucinations, often overpowering both the visual distortions and the task instructions. Participants reported being distracted, misled, or emotionally shaken. Several remarked on a change in their perspective, noting a greater sense of empathy or awareness after the experience.

Importantly, the visibility of the experience to observers varied greatly. In some groups, the headset users reactions were subtle or absent, making it difficult for others to relate or engage. In others, discomfort or confusion was clearly visible and provoked emotional reactions among the others. This variation highlights the importance of guided debriefs and shared reflection to fully activate the empathy potential of such simulations.

While the intervention may not have uniformly altered self-reported empathy scores, these qualitative accounts suggest that for many participants, the experience was personally impactful—emotionally and cognitively. Future iterations of this intervention may benefit from including structured reflective discussions or journaling to better capture and reinforce these internal shifts.

6.5 Summary of Key Findings

The results of this mixed-methods study suggest that while the MR simulation did not produce statistically significant changes in empathy scores across the entire sample, it nevertheless produced meaningful cognitive and emotional engagement for many participants. Pre-evaluation results indicated that students began the intervention with relatively high levels of empathy and attentiveness, leaving limited room for movement in quantitative scores—a classic ceiling effect. This was particularly evident in the Jefferson Scale of Empathy (JSE), where most participants scored in the upper range both before and after the simulation.

Post-evaluation data confirmed that self-reported empathy remained largely stable. Neither the total empathy scores nor the subcomponents of cognitive and affective empathy showed significant change following the simulation, and statistical comparisons (Wilcoxon signed-rank test) did not support the hypothesis of a group-level shift. Similarly, emotional affect scores from the B-PANAS showed only modest variation pre- and post-intervention, with none reaching statistical significance. Despite these findings, certain trends were observed, such as a slight decrease in attentiveness and modest increases in distress-related emotions for headset users, hinting at subtle internal shifts not fully captured by the quantitative instruments.

More revealing were the qualitative findings, which offered contextual insight into participants experiences. Headset users frequently described strong emotional reactions to the simulation, including difficulty focusing, feelings of helplessness and emotional discomfort. Many noted that the experience altered how they viewed people living with schizophrenia, leading to greater compassion and understanding. Observers, while less emotionally impacted, also reported increased awareness—particularly when they noticed visible signs of struggle in the headset user.

The simulation was broadly perceived as educational and realistic, with participants agreeing that it helped raise awareness about schizophrenia and could be valuable for those preparing to work in mental health care. In almost all groups, students expressed a desire to reflect more deeply on the experience, particularly during the structured debriefs. These reflections helped surface emotional and empathetic responses that were not always visible in the pre/post metrics but nevertheless shaped their learning.

In summary, the mixed-reality simulation appears to have fulfilled its educational intent by invoking a personal reflection and generating affective resonance, especially among those who engaged directly with the headset. While the immediate quantitative results were not statistically significant, the qualitative accounts indicate that the simulation meaningfully influenced individual perceptions.

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.

7.0.1 Interpretation of Changes

commentary on findings, potential explanations for lack or presence of effect, consideration of variability among participants, comment on potential improvements

While no significant change was observed in the overall empathy score, subtle shifts were detected in emotion-specific responses. For example, participants reported feeling slightly more "distressed" and less "ashamed" when thinking about individuals with schizophrenia post-intervention. However, these changes were not statistically robust in this sample.

Several possible explanations exist:

- A **ceiling effect** may have limited sensitivity, as pre-evaluation empathy scores were already high.
- The **short duration** between evaluations may not have allowed deeper attitude changes to form.
- Emotional responses may be more **situational or reactive** and less stable than overall empathy attitudes.

Further qualitative feedback could provide richer insight into participant experiences.

they did not look up for their task, which we should've forced a bit more, we don't know for sure if we are portraying the experience in a truthful way, they reported that they felt ashamed to move their hands to be judged by their peers, they were not able to focus on the task, which is a good thing, but we should've forced them to look up more often, the stains were actually useless

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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E r k l ä r u n g

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Studiengang: ....

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