FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

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WE ARE OULU: EXPLORING SITUATED EMPATHY THROUGH A COMMUNAL VIRTUAL REALITY EXPERIENCE

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ABSTRACT

Equality among all humans, regardless of ethnicity, language, or nationality, is an essential topic in every community and society. Immigrants' hardships as foreigners in another community are issues that not only contrast with humans' equality but also cause irreparable damage to foreigners and society. Nowadays, Virtual Reality (VR) as an alluring technology is a promising approach to communicating people's hardship experiences in a simulated situation to enhance others' empathy. It has even been called the ultimate empathy machine.

In this thesis, we developed a VR experience to showcase collected hardship experiences that the international community of the University of Oulu has faced during their studies and lives in Oulu to mainly local participants to explore their situated empathy. To this end, we first collected hardship stories and data from 40 members of the international community through an online questionnaire. The results highlight that social problems, language barriers, issues with bureaucracy, and racism are key issues in the community. Then, we developed and performed a VR experiment with 18 participants to let them read the hardship stories through simulated conversations and interactions with avatars in a virtual university environment. We asked our participants to respond to pre- and post-experiment questionnaires and participate in a semi-structured interview after the experiment. Analyzing questionnaire results indicated that after the experiment the average participant's responses to their knowledge and tendency to discuss the hardships increased by 1.05 and 1.11 on a 5-point scale, respectively. Likewise, their average responses comparing the international community's quality of life with themselves decreased by 0.77 on the 7-point scale, showing that they rated the international community's quality of life worse than they initially thought. The qualitative evaluation of participants' reflections yielded positive feedback on the VR experience's authenticity, the stories' plausibility, their increased situated empathy and awareness regarding the hardships, and VR as a promising technology in communicating these topics.

Ultimately, the thesis contributes to collecting and understanding the hardship experiences of the international community of the University of Oulu. It demonstrates a feasible approach to enhancing empathy and awareness, and the experiment increased the participants' understanding of the University of Oulu's international community's hardships. Further, the thesis continues to add evidence to how VR is a promising approach to fostering empathy.

Keywords: Empathy, Experiment, Hardship Experience, International Community, Unity Engine, University of Oulu, Virtual Reality.

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FOREWORD

The research presented in this thesis was conducted at the Center for Ubiquitous Computing (UBICOMP) at the University of Oulu, Finland.

I thank Prof. Timo Ojala for his significant support, analogous to a father, during my study at the University of Oulu. I would like to thank Associate Prof. Simo Hosio, the principal supervisor of the thesis, not only for his unlimited help in conducting this research but also for supporting me as a friend during my life in Finland. I thank Dr. Aku Visuri, the second supervisor of the thesis, for his priceless contribution and aid. Also, I thank my colleagues, Dr. Matti Pouke and Ville Paananen, for their outstanding help in conducting the VR experiment. And I would like to thank all my colleagues at UBICOMP Center and Crowd Computing Research Group.

I would like to thank my lovely intimate soulmate, Negar, not only for her incalculable support but also for being in my life. I thank my parents for their sacrifices to provide a better experience in my whole life. Also, I would like to thank all my friends that always support and encourage me to be a better person.

Conclusively, I would like to dedicate this thesis to Finland and its unique and friendly people. At the time of writing the thesis, I had around two years of experience living in this beautiful country. And two years was sufficient for me to comprehend what home means. I would try to make my home a better place to live, a happier country to dance, and a lovelier homeland to kiss.

Oulu, June 23rd, 2022

Mohammad Sina Kiarostami

LIST OF ABBREVIATIONS AND SYMBOLS

FBX	Filmbox
FOV	Field of View
GUI	Graphical User Interface
HCI	Human-Computer Interaction
HMD	Head-mounted Display
NLP	Natural Language Processing
NPC	Non-Playable Character
SD	Standard Deviation
UI	User Interface
VR	Virtual Reality
XR	Extended Reality

1. INTRODUCTION

Equality has always been one of the most critical topics in the contexts of social life and the new era of civilization [1]. Many scholars from decades ago have discussed equality in various areas [2, 3], approaches to achieve equality in society [4], its advantages and stakeholders, and disadvantages of inequality. There have been long discussions on ethnic and gender equality [5]. Nowadays, equality has more aspects in society's debate, such as human rights, freedom of speech, and social and public services accessibility, such as equality in education, healthcare, income, etc.

In today's life, communities, governments, and companies leading industries are becoming multinational and trying to eliminate distinct concepts of limitation and difference such as *Border* and *Discrimination* day by day [6]. Therefore, another aspect of equality shows off, which declares equality should be among domestic and international people in a society [7]. Although equality is an essential topic in all cultures and communities, it has more significant importance and effect in countries becoming prominent immigrants' destinations. In these countries, if society would not accept immigrants as one of its parts, social isolation, anxiety, and post-traumatic stress affect their quality of life, employment, and social status [8, 9].

Finland is one country that requires more foreign workers and experts. Based on a report in YLE News, Finland's national public broadcasting company, in July 2021, Ms. Annika Saarikko, the Finance Minister of Finland, affirmed that the government would require to expand Finland's foreign workforce to enhance the economy, services, and public services. For instance, social and healthcare authorities claimed that by the end of this decade, Finland requires 30000 more nurses to certify health services for the older population [10].

Alluding to the looming need for foreign labour in the country, the Finance Minister of Finland said, *"The fact is that agriculture, manufacturing, social and healthcare services−or, even mass transit in the capital region−would not function without foreign workers."* To this end, the current Prime Minister Sanna Marin's government has declared that it desires at least double work-based immigration by the end of the current decade [10, 11]. Put differently, the government and authorities have less than ten years to solve this problem while working on immigrants' absorption [10].

Likewise, due to Finland's national reports and official announcements, Finland faces a crucial problem: increasing and accumulating inequalities and social exclusion across generations [12]. This problem is superbly treacherous for Finland since not only does it cause severe damage to the society, such as the intergenerational transmission of poverty, discrimination, and increasing hardship experiences, but it also would decrease the rate of absorption of immigrants [12].

Although solving this substantial problem requires a significant collaboration among experts, scholars, authorities, and people, long hours of discussions, and a considerable cost, it would have many advantages [13]. Every group of people, industry, university, and government authorities would benefit from a society without this issue [14]. Finland would be an excellent destination for foreign experts and workers and attract them straightforwardly. Then, many economic topics such as lack of labor and experts would be solved [15, 16]. Industrial companies can expand their businesses and services nationally and globally. Public services from the government and authorities such as public health assurance and public transportation would not face difficulties.

And finally, the quality of life and satisfaction factor would be improved, and people would have a better life [14, 17].

In 1966, Weinberg [18] raised a discussion as *"technological fix"* by asking the question that *"Will technology solve all our social problems?"* This debate called scientists and engineers to employ technology to enhance society and human welfare [19]. Nowadays, technology plays a role in solving societal problems, such as equality and immigrants' hardships [20]. In this regard, many scientists have looked to enhance human empathy and understanding by using technology to foster equality and solve social difficulties [21, 22].

Further, and most related to this thesis, VR as an alluring technology is arguably one of the most promising technologies that can be employed to increase empathy [23, 24, 25]. Many researchers have indicated VR's effectiveness in improving people's situated empathy compared to similar technologies as tools to communicate social difficulties [26, 27]. It is also shown that VR can build long-term empathy in people [27]. Since VR allows subjects to experience a simulated situated empathy from a different point of view, many scientists have called it as *"the ultimate empathy machine"* [27, 28].

1.1. Approach

In our research, and with an implementation dubbed *We Are Oulu*, we investigate the hardships that the international community of the University of Oulu encounters, make society aware of them, and measure the participants' situated empathy [29]. Further, we hope to do this in a highly realistic, immersive way.

In the first step of the research, we designed a survey to collect any harrowing experiences such as language and cultural barriers of the international community of the University of Oulu, including international students, staff, and other related persons to higher education during their lives or studies in Oulu, Finland. Then, the second and third steps were organized as a VR experiment. Our participants listened to the first-step participants' stories and interact with VR avatars in the university's virtual environment. We measured the situated empathy via pre-experiment and post-experiment questionnaires and with a follow-up semi-structured interview with participants. Finally, we analyzed the results to shed light to our research questions. The questions as well as the objectives in this thesis were as follows.

1.2. Objectives and Research Questions

Considering all of the above, this thesis builds upon two objectives and answers three research questions:

1. **Objective I:** Collect information on the hardships that the international community faces at the University of Oulu.

2. **Objective II:** Develop a VR application to investigate communicating a subset of the collected hardships to the local community.

As a result, we explore three research questions:

1. **RQ I:** What kind of hardships are experienced by the international community of the University of Oulu?
2. **RQ II:** What effects does communicating the hardships of the international community have on the local participants?
3. **RQ III:** How suitable is VR as technology in communicating hardship experiences of the international community to the local participants?

1.3. Thesis Structure

The rest of this thesis is structured as follows: Chapter 2 introduces the preliminary topics, concepts, and technologies as the background of the study with investigating the related efforts. In Chapter 3, we explain the design of our survey to collect hardship stories from our international volunteers and elaborate on the survey results. Chapter 4 presents our implementation, technical aspects, and the VR experiment design. In Chapter 5, we analyze the experiment results and interviews. Chapter 6 discusses the study by reflecting on the thesis's objectives, research questions, and other relevant topics. Additionally, we introduce our future work in this chapter. Finally, we conclude the thesis in Chapter 7.

2. BACKGROUND AND RELATED WORK

This section introduces preliminary concepts that are required before going through the study to comprehend better its different aspects, such as the study design and technical implementation. It includes several related domains and definitions to our proposed project, such as introducing *Human Empathy* and investigating several approaches and efforts to measure it. In addition, we also present the essential technical topics required to be familiarized.

2.1. Human Empathy

Collins Dictionary defines empathy straightforwardly as *"the ability to share another person's feelings and emotions as if they were your own"* [30]. Also, in *Merriam-Webster* dictionary, there is a general definition of this word as follows: *"The action of understanding, being aware of, being sensitive to, and vicariously experiencing the feelings, thoughts, and experience of another of either the past or present without having the feelings, thoughts, and experience fully communicated in an objectively explicit manner"* [31].

As indicated above, empathy as a word has a general and accepted definition. In scientific and academic articles, researchers mentioned that empathy is a concept that everyone has an understanding of and what it means. However, there is no generally approved scientific definition for this concept in scientific literature [32]. As Reniers et al. [32] stated, there have been discussions on whether empathy includes *"recognizing emotion"*, *"experiencing emotion"*, or both that do not allow to complete an extensively approved definition of empathy [33, 34, 35]. Similarly, there has been a debate among scientists to consider behavioral responses in the definition of empathy, which also cause not to end up with a single approved definition [32, 36, 37].

Nevertheless, there have been many efforts to bring a clear definition of what human empathy means. Cohen et al. [38] defined empathy as *"the understanding and sharing in another's emotional state or context."* Hodges and Myers [39] focused on comprehending others' experiences and expressed that *"empathy is often defined as understanding another person's experience by imagining oneself in that other person's situation."* Furthermore, many scholars investigated the history and meanings of empathy in different contexts, such as in Human Sciences, Psychology, Medicine, Social Sciences, etc., to achieve an acceptable definition of empathy [40, 41, 42].

Furthermore, many researchers explained that empathy contains several factors and definitions. It means that empathy should be defined based on several other meanings, which shows that empathy is not a single term with a single description. Blair stated that empathy is a lay term that includes *Theory of Mind*, *Motor Empathy*, and *Emotional Empathy* [43]. Blair also supported this definition of empathy with an experiment showing that individuals with autism have difficulties with cognitive and motor empathy while lesser troubles are observed with emotional empathy [43].

Theory of Mind, which was formerly referred to as *Cognitive Empathy*, is the ability to represent others' internal mental states, such as other individuals' thoughts and desires [43, 44, 45, 46]. Nowadays, cognitive empathy is defined as one person's understanding of other individuals' experiences by placing themself in others'

experiences [32, 47]. Motor empathy is defined as a response that *"unconsciously mirroring the facial expressions of another"* [48, 49, 50]. Emotional empathy, which is also called *Affective Empathy*, is defined as a response to experiencing emotions and *"the ability to share the feelings of another person"* [51, 47, 52]. Furthermore, many scientists approved cognitive and affective empathy concepts and their differences in their research [53, 54, 55, 56].

As Reniers et al. [32] discussed, cognitive and affective empathy are two required components of human empathy, but based on their definitions, they would be enabled with different approaches. Therefore, they brought a new formulated description of empathy by considering all assumptions, such as excluding behavioral expressions and reactive emotions like sympathy [32]. Sympathy is distinct from empathy since it is not part of empathy but is considered an output of empathy [23, 32]. Consequently, Reniers et al. [32] defined empathy as a combination of cognitive empathy, constructed by perspective-taking and online simulation, and affective empathy, containing emotion contagion and proximal and peripheral responsivities.

In this thesis, we refer to Reniers et al. [32] for the definition of empathy and its components, as discussed in the later paragraph.

2.1.1. How to Measure Empathy

Due to the significance of measuring empathy in many research areas, such as Human-Computer Interaction (HCI), Neurology, Social Psychology, etc., there are many efforts to measure empathy accurately [57, 58]. Researchers have developed different approaches for this purpose. Stueber [59] expressed that measuring situated empathy could be done by asking about subjects' experiences and feelings exactly after the situation, studying *"facial, gestural, and vocal indices of empathy-related responding"* [60], or analyzing physiological measurements such as heart rate [59].

Reniers et al. [32] claimed that self-report questionnaires are the best choice for measuring subjects' situated empathy. There is a debate whether even self-report tools could affect subjects' empathic responses [59]. For instance, subjects' abilities to understand and express thoughts and feelings or distinguish between empathy and sympathy are influential factors [59, 60, 61].

However, scientists developed many self-report tools and questionnaires to enhance this approach and overcome mentioned issues. For instance, many questionnaires ask several questions about a concept with different contexts, tones, and meanings to ensure subjects understand the questions and answer accurately empathic [32]. In contrast, some researchers developed questionnaires with a fewer number of questions to ask subjects about the situated empathy immediately effectively. In this regard, Konrath et al. [62] have developed the Single Item Trait Empathy Scale (SITES) that takes seconds for participants to answer.

Dymond [63] developed one of the first valid and reliable empathy questionnaires with 24 items on a 5-point scale of 0 to 4 in 1949. After that, Block [64] created CPI Q-sort with 100 True or False items with wide dimensions such as social presence and self-acceptance. And a few years later, The Empathy Scale was formed by Hogan [65] and contained 64 items on a 5-point scale of 0 to 4. Then, Mehrabian and Epstein [66]

introduced the Emotional Empathy Tendency Scale or EETS on a 9-point scale of -4 to 4 that includes emotional dimensions.

Furthermore, Davis [67] developed a well-known empathy questionnaire, IRI - Interpersonal Reactivity Index, in 1980 with 28 items on a 5-point scale of 0 to 4 that contains empathic concerns, perspective-taking, and personal distress. Two years later, Bryant [68] created the Index of Empathy for Children and Adolescents with 22 items on a 9-point scale of -4 to 4. Later, Mehrabian [69] developed the BEES - Balanced Emotional Empathy Scale, with 30 items on a 9-point scale of -4 to 4. Hojat et al. [70] created The Jefferson Scale of Physician Empathy with 20 items on a 7-point Likert scale of 1 (*Strongly Disagree*) to 7 (*Strongly Agree*). Baron-Cohen and Wheelwright [71] introduced EQ - The Empathy Quotient with 60 items and a shorter version with 40 items on a 4-point Likert scale of 1 (*Strongly Agree*) to 4 (*Strongly Disagree*). Later, Spreng et al. [72] presented The Toronto Empathy Questionnaire with 16 items on a 5-point Likert scale as *Never, Rarely, Sometimes, Often, Always*.

Recently, Reniers et al. [32] developed The QCAE - Questionnaire of Cognitive and Affective Empathy with 31 items on a 4-point Likert scale of 1 (*Strongly Disagree*) to 4 (*Strongly Agree*). The QCAE is based on the new general definition of empathy and calculates the empathy score of individuals based on both cognitive empathy and affective empathy. Also, The QCAE has many distributed items to handle any issues subjects might have with understanding or estimating their thoughts and empathy.

Due to the explored argument above, we employ the QCAE [32] in our study to measure our participants' situated empathy.

2.2. Virtual Reality

Virtual Reality (VR) is defined in two similar ways. First, VR is a term for a simulated experience or, more specifically, *"an immersive, multi-sensory experience"* [73], whether it can be realistic or not [74, 75]. Also, it is defined as a technology or, more specifically, a human-computer interface that provides an unreal experience with diverse available functions for subjects in a simulated environment that could be similar or different from the real world [75, 76].

Nowadays, VR is a well-known technology and has many applications in people's lives and different industries, such as Entertainment and Computer Games, Education, Space and Military, and Online Meetings [25, 74, 77].

VR was chosen as the technology to build upon in this thesis. Therefore, the following sections present related work conducted with VR.

2.2.1. VR Technologies

In this section, we introduce two prominent technologies that we employ as tools to develop our VR application for the thesis.

Virtual Reality Headset: Oculus

In VR, like other technologies, we require a device to be able to employ VR as a technology with it to simulate an experience from an application. VR headsets are an essential technology that enables VR developers to provide a simulated experience as it is designed to be, for instance, immersive. Generally, a VR headset contains a *Head-mounted Display (HMD)* with several sensors and cameras to track the user's body and head movement [78]. HMD is a display device that can be fully installed on the head like helmets or worn on some parts of the head, similar to eyeglasses [78, 79]. We should mention that many VR devices contain controllers to allow users to interact with the virtual environment during the simulated experience.

There are many high-tech companies, such as *Oculus (Meta)*, *HTC*, *Samsung*, etc., that develop and create several different types of VR devices commercially. Oculus company, which is now part of Meta company, is one of the pioneers in this area that recently developed the most advanced all-in-one VR system, namely *Quest 2*, which allows users to run VR applications directly in the VR headset with an endorsed performance [80].

Game Engine: Unity

A game engine is a software framework that includes libraries, tools, supported assets, and programming languages, often with a *Graphical User Interface (GUI)* to allow developers to create and design a computer program, primarily video games for different platforms [81, 82]. There are many commercial game engines that are developed or supported by high-tech companies, such as *Unity* and *Unreal* game engines. *Unity Technologies* developed the Unity game engine, which is now one of the most well-known engines among developers for creating video games, mobile applications, electronic books, etc. [83].

Each game engine has its supported features and platforms. Unity supports `C#` and *JavaScript* programming languages to create applications on most commercial platforms such as *Windows*, *Android*, *Linux*, *Play Station*, etc. Therefore, the Unity engine has also become a famous third-party developer tool. Furthermore, Unity benefits from a vast community and has an asset store with numerous free and paid assets to enhance and customize the engine and accelerate the development process [84]. In the thesis's scope, Oculus and other developers have created many toolkits and libraries to make developing a VR application more straightforward [85, 86, 87].

In this thesis, since we develop a VR application as part of the project on the Quest 2 device, the Unity engine supports Android, which is the device's operative system.

2.2.2. Virtual Reality for Research and Empathy

Many efforts have been made to enhance either VR devices and technology by itself or user experiences to improve the simulated experience's performance to make VR the future mainstream technology [88, 89]. Zhang [90] expressed the concept of *I3* in VR as *Immersion*, *Imagination*, and *Interaction*. Therefore, many researchers in VR target these three critical concepts. Bowman et al. [91] introduced the potential benefits of increasing immersion in VR. Fang et al. [92] described a new mobile approach for

employing haptics in VR to allow users to have a more pleasant experience in VR by using their bodies' feedback for interaction despite using controllers. Also, many researchers investigated the side effects of VR on humans, such as motion sickness and dizziness [93].

VR has many effects and functionalities in the academic world. Many researchers employed VR as a tool or approach for their research on various topics such as computer games [94], HCI [29], Medicine [95, 96], Education [97], and Social Studies [98]. To bring several instances, Oyelere et al. [99] investigated the trends of educational VR games. Boletsis et al. [100] expressed that VR affected HCI research and attracted researchers' interests. Bracq et al. [101] assessed a VR simulator's usability and accessibility in training scrub nurses. Lu et al. [102] also proposed a VR game to help children with autism in learning.

Furthermore, there are several efforts in the scope of this thesis which is employing VR as a tool for simulating or indicating a situated empathy experience [29, 103, 104]. For instance, Steed et al. [22] created an immersive scenario with VR to showcase the situation of refugees waiting for a boat to escape to measure situated empathy. Oyekoya et al. [105] also explored empathy among a focus group about bully prevention with a first-person perspective in VR and suggested considering VR as a practical approach.

Paananen et al. [25] reviewed several studies that have been done on empathy with VR. Martingano et al. [106] expressed that VR can improve affective empathy but not cognitive empathy. Louie et al. [107] discussed that enhancing empathy is a new role for VR. Bujic et al. [21] proposed that people's attitudes regarding human rights can be changed via media content through an immersive experience with VR. VR also has been used to improve parents' understanding regarding their children with sensorineural hearing loss by enhancing empathy [108].

Several researchers indicated that through experiments with the same scenarios and conditions, VR makes people more empathic compared to other technologies. Shashkevich [109] investigated through many VR studies at the Stanford University that VR can make people more empathic compared to other media. Christofi et al. [26] investigated empathy regarding daily drug users' situations in two similar scenarios with VR and desktop monitors and showed VR had a more substantial effect on their participants.

Abadia et al. [110] presented that immersive VR enhanced empathy as their participants with VR were more empathic regarding a World War II story in comparison with other the other group. McEvoy et al. [111] also showed that VR's effectiveness in enhancing empathy about a bullying situation is more compared to a video. Herrera et al. [27] indicated that people who experienced homelessness in VR had a more empathic and longer-lasting attitude than those with traditional perspective-taking. Likewise, many researchers indicated that VR is an effective tool to enhance empathy and called it the ultimate empathy machine [28, 112, 113, 114].

3. PRE-EXPERIMENT DATA COLLECTION

This chapter explains our first step of the study, which is the preliminary survey and story collection design. We clarify what we would like to collect and investigate, our approach to collecting required data, and how it achieves our study objectives and research questions. We also focus on our preliminary data collection with explanations regarding our survey, its design, and our findings.

Finally, we investigate all data collected through the story collection phase, demonstrate our findings and selected stories based on their topics for the next step of the study.

It is worth mentioning that in this stage of the study, we implement a website, namely *We Are Oulu* that was, at the time deployed, at the online domain weareoulu.com. Implementing a project website was essential to us due to several reasons. First, to put all the project's details and purposes, and secondly collect our required data through the website, as we explain further in the upcoming sections.

3.1. Story Collection Survey Design

As discussed in Chapter 1, our study had three foremost steps to be implemented and experimented. We have the story collection step as the first step to collect and employ true stories based on the hardships international members of the University of Oulu, such as students, staff, etc., experienced. Engaging those experiences in the experiment has two critical aspects. First, it would reflect an accurate image of what international people experience during their lives in Oulu without any modification, exaggeration, or underestimation. Secondly, the experiment could impact participants' empathy when they realize those stories happened one day in someone's daily life.

To collect the mentioned data anonymously and privately, we required designing a survey and sharing it among potential participants. Therefore, we created a survey by *Google Forms* and shared the link on the project's website, as we elaborate more on the project's website in Section 3.1.1.

We let participants fill the survey out anonymously with their consent and complete awareness of the project, details, and purposes, as demonstrated in Section 3.1.2. We should mention that we randomized all collected data to remove any possibility of privacy revealing during the story collection. Later, we exemplify the two primary types of questions we ask in the survey in Section 3.1.3.

3.1.1. Website

As mentioned earlier, we needed the website to arrange all details regarding the project, such as a full explanation of what the project is about, who the responsible persons are, and what organizations or research units support the project. It helped our participants to comprehend what the project was about, and then they could choose to participate or not.

Also, we distributed our survey for the collection as a link to our website and invited our potential participants rather than sending a Google Form link to the email lists.

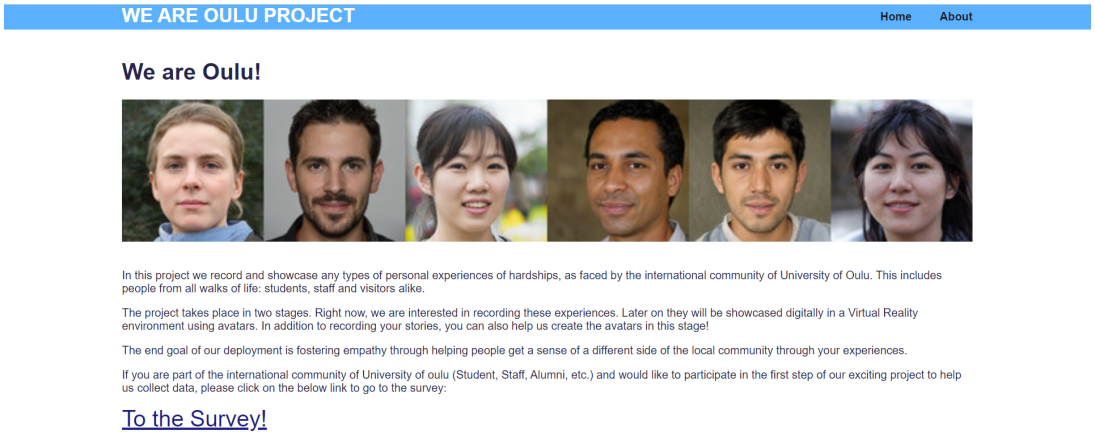

Figure 1. An overview of *From Scratch* version of the project's website on Heroku.

Therefore, to initiate the story collection, we required implementing a website for the project.

Initial Approach: Heroku App

The first approach was implementing the whole website with tools such as *HTML (HyperText Markup Language)*, *CSS (Cascading Style Sheets)*, and *Python*. We developed a website from scratch with *Flask*, a micro web framework in the Python programming language. Indeed, we employed Flask to create the structure and directions to different website pages and maintain it as a Flask application. Other than that, we also used the HTML programming language to make various parts of each page and the page structures and utilized CSS to design the user interface correctly.

The first draft of the project's website with explained libraries and programming languages was concluded with a simple website containing two web pages, as indicated in Fig 1. These two web pages were titled *Home* and *About* to include information regarding the project and the responsible research group orderly. As mentioned earlier, one of the most prominent goals of implementing a website for the project was to distribute and advertise the data collection professionally by sharing the project's website. So, we placed a hypertext as *To the Survey* to link our Google Form to the website.

The website was launched on the *Heroku* platform, which is a cloud platform as a service company that supports several programming languages, such as Python. Since we employed Python in our implementation, Heroku was one of the most efficient options to deploy the website with zero cost. Also, using Heroku was very straightforward since it builds and deploys the application automatically. The naive approach was discarded for several reasons explored in the rest of this section.

First, the website was not a responsive web page. This issue was critical in our project since we had several participants or visitors who used mobile phones or personal computers with different display settings. In addition, if we would like to improve the user interface and design of this version or enhance the website, this approach would be time-consuming.

Figure 2. An overview of *Cross-platform* version of the project's website powered by Carrd.

So, based on the reasons argued above, our approach was changed to create our website with site-building platforms to access broader and better implementation options and save time and energy in the project. The following section explains our next solution to implement a good-looking website with improved functionality.

Cross-platform Approach: Carrd

In this section, we discuss our approach to implementing the final website for the project. Our solution was to employ third-party applications to develop the website with tools rather than programming languages. We selected this approach for two crucial reasons, as we elaborate on them in this section. In addition, we clarify the reason why the *Carrd* platform is our chosen third-party platform to develop the website.

First of all, we required to reduce the production time to focus more on the research part of the project despite the engineering part. Therefore, as argued in the previous section, the development of the website with the initial approach would take a lot of time, which was unnecessary.

Secondly, as discussed before, we required a professional website to attract our potential participants and collaborators. For instance, we needed a responsive website to let users see the content correctly on mobile or desktop devices. Developing these options would take a lot of time and unnecessary effort.

Therefore, we continued our web development with a cross-platform approach due to the above argument. In this approach, we wanted to employ a tool to build a high-quality website with the lowest need for programming. To this end, there were several platforms and companies, that provide this solution, such as *Wix*, *Carrd*, and *WordPress*.

Carrd was selected due to its low cost, easy-to-use, and fast publishment features. Besides, it created a one-page website by linking different designed pages with simple redirection methods embedded in the buttons. It means that we did not have to make

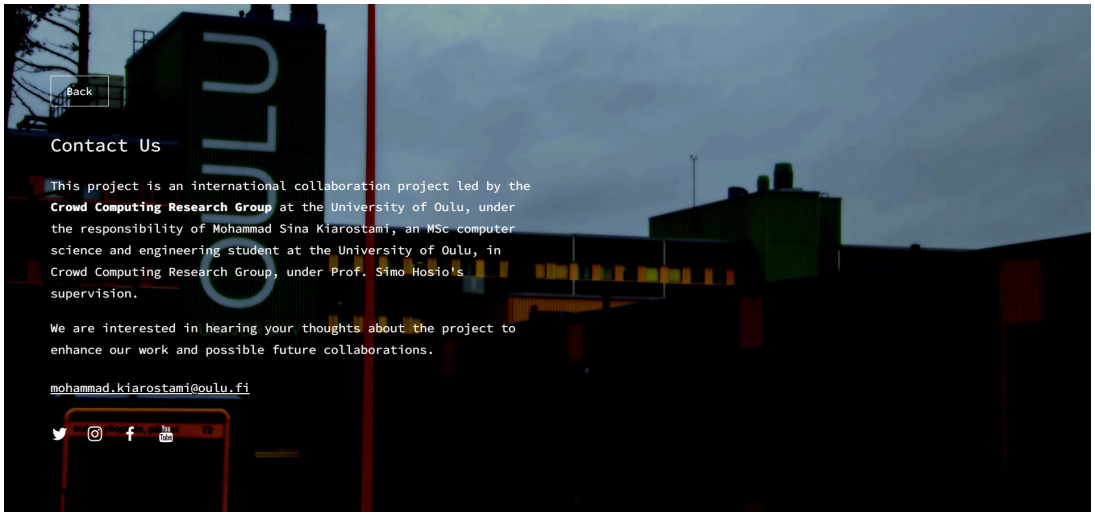

Figure 3. An overview of *Contact Us* page of the project's website.

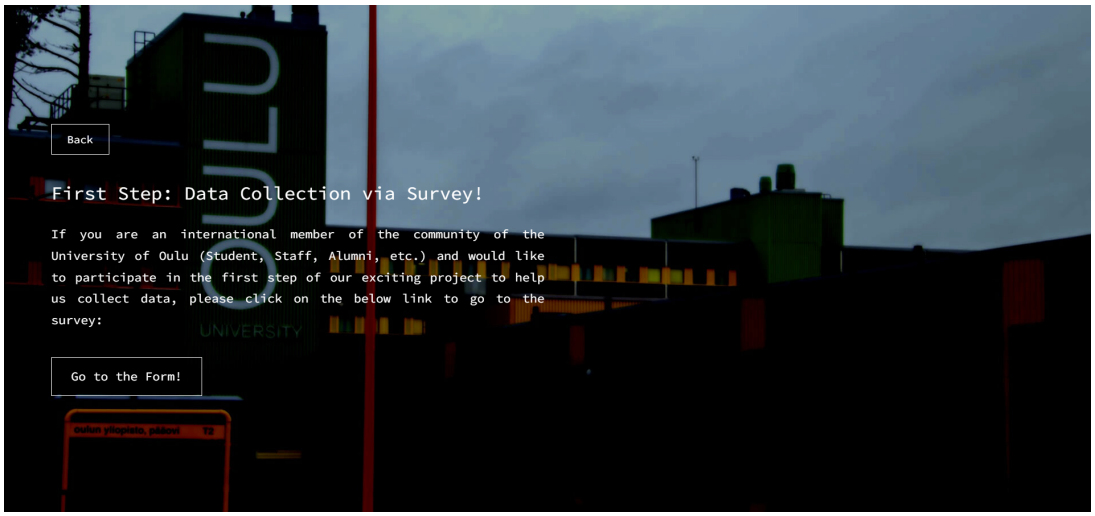

Figure 4. An overview of *To The First Step* page of the project's website.

several pages and developed them separately. We only needed to define buttons on each page and then linked distinct page parts to other parts.

Thanks to the Carrd platform, the website was prepared and launched fast. For instance, we employed an edited photo of the University of Oulu on the main page, as shown in Fig 2. Then, we defined a text box to write down our explanations regarding the project's details. In addition, we represented several buttons to direct users to other parts of the website. There were two buttons on the main page, called *To The First Step!* and *Contact Us* to redirect users to these parts. Furthermore, On the main page, we put the logos for our research group and our research unit, Crowd Computing Research Group and Ubiquitous Computing Research Unit (UBICOMP), respectively. It could increase the project's validity.

The Contact Us page included contact information about the responsible persons and the research units who defined the project, such as email and social media addresses. Fig 3 shows a snapshot of the Contact Us page on the website.

We had another button, titled To The First Step, on the main page, as mentioned earlier. This button directed visitors to the first step of the study. As indicated in Fig

4, we introduced the first step of the experiment here, which was the data collection. Since we wanted to collect international people's hardship experiences, as discussed previously, we provided a short explanation about what this step was and who we required for this step as participants. There was a button on this page, which is titled as *Go to the Form*. This button was linked to our questionnaire for the data collection.

All in all, based on the whole arguments we explored above, our final version for the project's website was created with the Carrd platform.

3.1.2. Consent Form

Since we collected different types of participants' demographic data such as nationality, ethnicity, etc., and background information such as age, years of living outside the home country, etc., it was required to have a consent form in the data collection survey. Also, participants told their hardship experiences and personal stories through this survey. So, they had to be aware of the study's purpose, responsible researchers, and the project's stakeholders' information.

To this end, the survey had an explanation regarding all the information that participants must know about the study. When participants wanted to fill the survey out, they had to read this explanation about the study. It described the research and its goal first and then explains what this survey is and why it relates to the study. After that, it clarified the project's responsible researchers and data collection.

Finally, there was a pre-made statement for participants to declare that they knew all the necessary information, such as their right to withdraw, and permit us to use their data and stories for research and academic publications. This statement is as follows:

"I understand that routinely data collected about me in this research will be used to evaluate and create a defined study with a clear purpose at the University of Oulu. I understand that the data will be anonymized before analysis. Any report, academic article, or dataset will not contain any information that could be used to identify me after publication. My identity will be kept private. I understand that I have a free choice of whether to agree to participate in this study or not without any effect."

This statement was designed as a required question in the Google form to let participants sign it by checking a sentence as follows:

"I agree to participate in this research."

By checking this sentence as a choice, they could continue to fill the survey out and go through the questions.

3.1.3. Questions

The data collection survey had two sections in the Google form. In the first section of the survey, we asked participants to describe any hardship that they had experienced during their lives in Oulu or studies at the University of Oulu. Also, in the rest of the first section, we asked several demographic and background questions, which we demonstrate in detail in the following subsection.

In the second section of the survey, we asked one question from participants. We invited them to use their wording and tone to describe their stories. In total, we had two

Figure 5. An example is employed in the story collection survey to help how to convert hardship experiences to stories.

main types of questions, called *Preliminary and Demographic Questions* and *Story Collection Questions* in this survey. For clarification, we should mention that Story Collection Questions were in both sections of the survey. In the rest of this section, we present each group of questions in more detail.

Preliminary and Demographic Questions

We asked about participants' gender, ethnicity, current status regarding Finland's higher education system, their experience living in other countries, and their consideration about being judged by their nationality in the community as multiple-choice questions.

We asked their age and the number of years they had studied or lived in Finland as short answer questions. Also, we invited them to say their nationality as a dropdown question. And finally, we asked our participants one question as a linear from 1 (*Extremely Unsatisfied*) to 5 (*Extremely Satisfied*) to compare their quality of life in Finland with their home country or other countries they studied or lived there. In Section 3.2.1, we present the results and our findings in detail.

Story Collection Questions

These questions were critical in our survey since participants should feel free to share their personal experiences regarding a hardship they had faced. In the first section of the survey, as the first and essential question, we asked our participants to share difficulties of any kind they experienced in their life at the University of Oulu as a non-native member of this community. In this question, we also clarified that the hardship included, but was not limited to, cultural barriers, language problems, issues with immigration, residence permits, anything related to bureaucracy, daily interaction with other community members or social problems, racism, etc.

In the second section of the survey, we asked our participants to write down their experiences mentioned above in the form of a story or bubble speech to let us describe

their experiences as they would like and employ their tone and original words in the experiment. The question was asked in the survey as follows:

"Change your earlier hardship description into a "speech bubble," i.e., how would you tell shortly about your experience to someone in just a few sentences or even less?"

As illustrated in Fig 5, an example was placed in the question's description to clarify what we would like. This section of the survey concentrated only on converting hardship experiences into stories. Further, as we explain in Section 3.2.2, these stories made our avatars' stories for the experiment.

Furthermore, it is worth mentioning that we initially aimed to ask our subjects to take a selfie photo and upload it via the form in this section if they would like. This option would allow us to create their avatars based on their pictures in the virtual environment.

Also, it is understandable that some participants would not like to share their identities due to personal reasons, preferences, etc., especially when they talk about their personal hardships. So, it could be an option to ask them to upload a random copy-right free selfie from the internet or even not upload any photo to let us know they would like to be completely anonymous.

However, we eliminated this part from our story collection survey since it might let participants abandon the data collection for several reasons. First, the extra required effort to take a selfie and upload it to *Google Drive* or other relevant websites even if they would be satisfied with sharing their identity. Secondly, the other option also needs them to find a copy-right free image on the internet. Also, as explained before, many participants would have problems sharing their identities during this experiment.

3.2. Results of the Story Collection Survey

This section presents the results of the story collection survey in two primary parts. In the first part, we present our findings and statistics regarding the answers collected from our participants in the first category of the question, which is preliminary and demographic questions, as explained previously. The second part concentrates on the hardship stories and experiences gathered from the second category of the questions, story collection questions. We also explore the topics of the stories and select some of them for the experiment as avatars' stories.

3.2.1. Preliminary Findings and Statistics

The story collection survey was advertised and shared among potential participants via several distinct approaches. All the information regarding the study, such as its purpose, the project's website, and the survey's link shared through our social media channels such as *LinkedIn* and *Twitter*.

Direct approaches, such as sending an invitation email to the study with a short introduction via students and staff email lists, were also employed. Onsite methods, such as participating in international events at the university such as *Cafe Lingua* to invite people directly, were one of the ways to find our participants. After all these efforts, we had 40 responses to this survey.

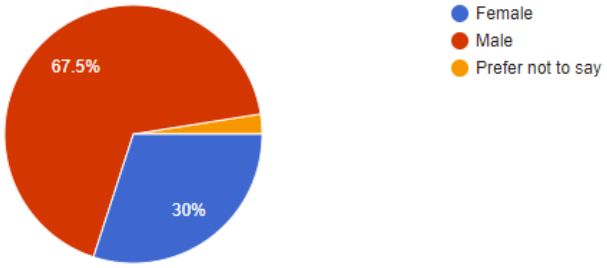

Figure 6. Participants' genders statistics.

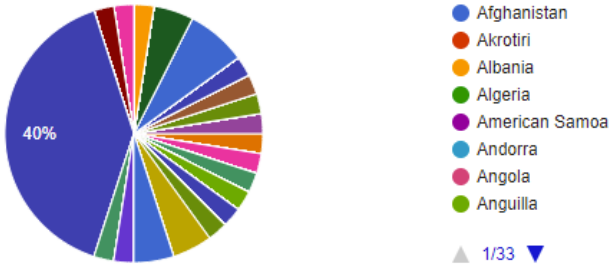

Figure 7. Participants' nationalities statistics.

As shown in Fig 6, among all our 40 participants, 27, 12, and 1 participants claimed their genders as Male, Female, and Prefer not to say, respectively as follows: 67.5% Male, 30% Female, and 2.5% Prefer not to say.

The range for their age was from 20 years old as the youngest age to 52 years old as the most aged participants. Also, 26 and 32 years old ages had the highest number of counts with 12.5% and 10% of the whole participants. The mean and Standard Deviation (SD) for participants' ages are 30.12 and 6.76, respectively.

In total, we had participants for this survey from 20 different nationalities. As illustrated in Fig 7, 16 participants were from Iran, containing 40% of all participants. After that, 7.5% of our participants were from Sri Lanka, which means 3 participants were from this country. Then, we had 2 participants from each of these countries in alphabetical order: Ghana, Greece, and Spain, each country with 5% of the total participants.

Finally, we had 1 participant from each of the following countries, also in alphabetical order, each with 2.5% of the total number of participants: Australia, Belgium, China, Ecuador, France, Germany, Honduras, India, Kashmir, Luxembourg, Pakistan, Portugal, Turkey, Ukraine, and the United States of America.

As displayed in Fig 8, our participants announced their ethnicity from the six major ethnicity categories from the highest number of participants to the lowest as follows: 45% Asian, 37.5% White, 12.5% Hispanic or Latino, and 5% Black or African American.

Regarding our question about participants' current status in the higher education system in Finland, we had a wide range of responses. As shown in Fig 9, from the highest number of participants to the lowest, 47.5% of our participants were MSc

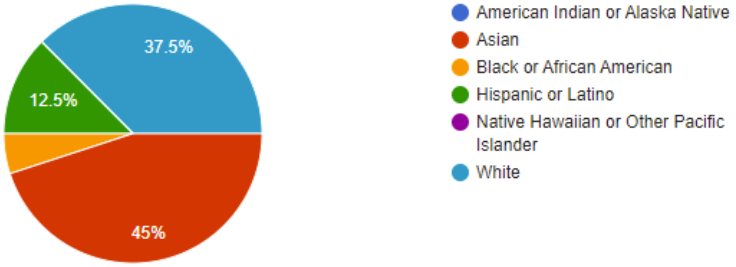

Figure 8. Participants' ethnicities statistics.

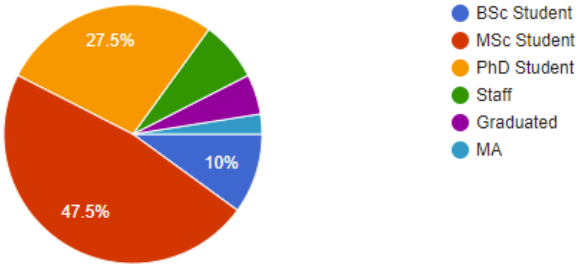

Figure 9. Participants' current status regarding the higher education system in Finland.

students, 27.5% Ph.D. students, 10% BSc students, 7.5% Staff, 5% Graduated, and 2.5% *"MA"*. We should explain that since we also had an option to put their desired answer, one of the participants answered this question as MA.

Furthermore, we also had a wide range of answers regarding the years our participants lived or studied in Finland. We had participants who lived in Finland for less than one year and about 25 years. The majority of the participants have lived or studied in Finland for two years or less. The mean and SD for participants' years of living or studying in Finland are 3.13 and 4.16, respectively.

The majority of the participants, which is 52.5% of the total participants, had experiences in living in other countries, while 47.5% expressed they did not have any experience other than Finland, as indicated in Fig 10.

As illustrated in Fig 11, 72.5% of participants were rated as 4 and 5 to compare their life in Finland with their home countries or other countries they studied or lived. We should mention that 5 means *Extremely Satisfied* which shows that most of our participants rated their quality of life as more than average compared to other places they experienced living there. The figure demonstrates that 20% of the participants rated it as the average, and 7.5% of them ranked lesser than the average. The mean and SD for participants' responses to this question are 3.77 and 0.76, respectively.

Finally, as revealed in Fig 12, among all of the participants, 37.5% of them declared that they had not been judged by their nationalities in the community, while 32.5% claimed the other side. Moreover, 30% of the participants think they maybe have been judged due to their nationalities.

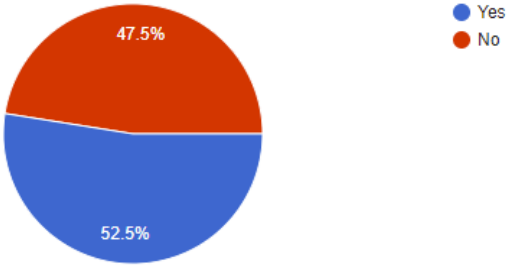

Figure 10. Participants' experiences in living in other countries.

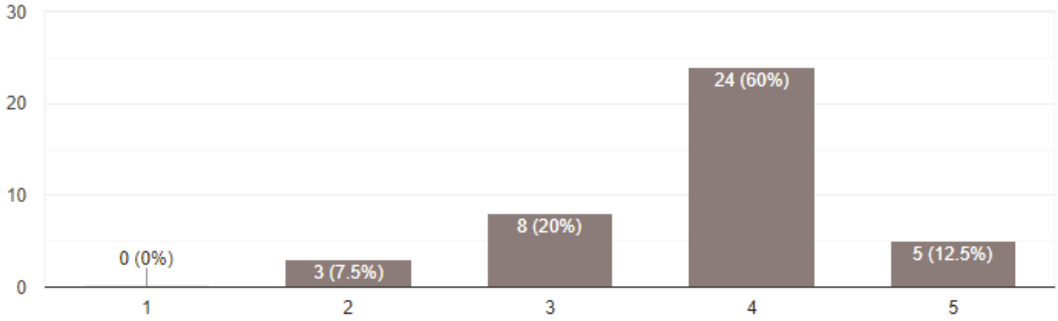

Figure 11. Participants' scores to their lives in Finland in comparison with their home countries or other countries they studied or lived.

3.2.2. Stories

This section demonstrates the results of the second category of the questions in our story collection survey, as discussed in Section 3.1.3. We first explain the topics of the stories collected from all the participants and then present the selected stories for the experiment.

Topics

The topics of the stories covered various aspects of an international person in Finland, such as difficulties in finding friends, struggling to be merged with the domestic communities, language, cultural barriers, etc. We mentioned in the survey question that participants could talk about any hardship experiences that they wanted, and the responses were varied. Several participants expressed more than one topic in their hardship experiences. For instance, the following answer from one of the participants refers to three issues which are related to bureaucracy, finding Finnish friends, and the weather. The answer is as follows:

"Opening bank account was really hard and late, Finding Finn friends was also hard. It's really cold here."

However, some of the stories focused on one topic. For instance, the following story describes its writer's financial concern during study in Finland and its effects:

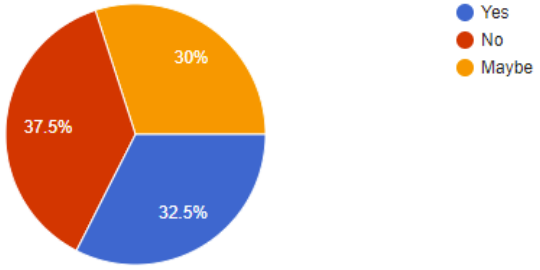

Figure 12. Participants' considerations regarding their experience in being judged by their nationalities in the community.

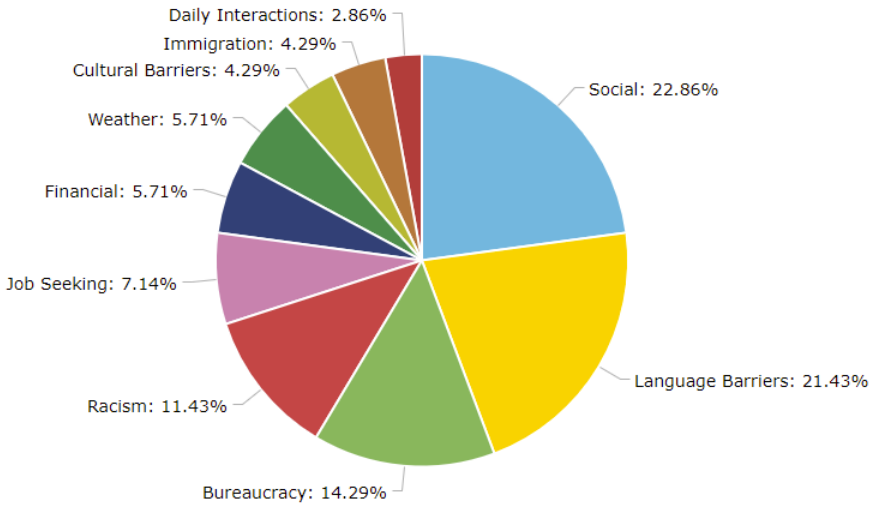

Figure 13. Distribution of participants' topics of stories.

"Financial concerns that were exacerbated by the pandemic had a detrimental effect on my motivation and ability to concentrate on my studies."

After reviewing all the responses' stories, the author of this thesis performed an initial categorization of the responses by applying a thematic analysis [115] and was validated by a colleague. We employed a standard approach to perform the thematic analysis with six primary steps: familiarization, coding, generating themes, reviewing themes, defining and naming themes, and writing up, as explained in detail by Caulfield [116]. We named a code for each problem discussed in each story and then put stories with similar codes in a category.

As illustrated in Fig 13, we categorized the stories' topics into several primary issues in order of most mentioned topics to less as follows: Social 22.86%, Language Barriers 21.43%, Bureaucracy 14.29%, Racism 11.43%, Job Seeking 7.14%, Financial 5.71%, Weather 5.71%, Cultural Barriers 4.29%, Immigration 4.29%, and Daily Interactions

2.86% of the topics. This figure also reveals that language barriers and social problems such as finding friends and getting involved in the community are the most mentioned issues for the international community.

Selected Stories for the Experiment

As we elaborated earlier in Section 3.1.3, the story collection survey attempted to collect participants' hardship experiences. Then, the second section of the survey asked participants to convert their answers into the form of a story. However, several participants did not understand the purpose of this question. For instance, one of the participants answered the second section of the survey as follows:

"I did not understand"

Several participants modified their hardship experiences into a single-sentence story. For example, one of the participants converted their hardship experience into this sentence:

"People are looking friendly sometimes but not always :)"

Although this sentence is natural, it is not in the shape of a story that contains enough information and details. If we employed this sentence as a story in the VR experiment, many participants would not understand how and why this hardship happened to that person.

However, as discussed in the previous section, many valuable stories were available for the VR study that covered a wide range of possible issues and difficulties in a non-native member's life. Therefore, the author of the thesis first compared all stories and selected five stories to cover most of the mentioned issues. Then, the selected stories were discussed with two colleagues to be validated for employment in the experiment. Also, it was consdiered to choose longer stories to provide a better vision with details of the stories to participants.

We should note that some of the stories that we employed for the experiment were a combination of several relevant stories. Additionally, the tone and wording for the stories remained the same to prevent any changes, exaggeration, etc. We only corrected the typos and grammatical errors in the stories. The selected stories are as follows:

Story 1: This story is a combination of two participants' stories and was chosen since it refers to three critical issues: Social, Language Barries, and Racism. The story is as follows:

"Connecting to Finnish people is hard, especially since they switch back to Finnish even with having non-Finnish speakers around. However, hobbies might help in the end to get closer to them.

Only once did I have an experience when a bit older Finn was calling me a Nazi behind my back for being from Germany. He refused to talk to me in English during all future meetings after he heard me saying that I was from Germany. After talking to the other teammates, they told me that he has strong prejudices toward me for my origin."

Story 2: This story is from one of our participants who discussed both positive and negative sides of being in the community as a non-native member. It brings a detailed example that supports the discussion. The story is as follows:

"On the whole, I felt like Finns were very helpful towards me. However, I know this to not be the case for many of my mates. Whilst I cannot speak on their account, I did witness many occasions when we were out in public, at the pub, for example, where

locals would treat my friends differently than they would treat me. This I derived was based on their ethnicity.

This happened to my friend from Iran, my friend from Greece, and my friend from Finland, who is of Sudanese descent. In regards to the latter, there was one instance when we were together at a bar talking English, and he was abused for not talking Finnish in Finland. Unbeknownst to this woman, Finnish is his mother language, so she was shocked when he replied in Finnish. Unfortunately, this was just one example of many."

Story 3: This story is also from one of our participants who described a detailed personal story that mentions many vital topics such as Financial, Job Seeking, Language Barriers, and Immigration difficulties. The story is as follows:

"My biggest hardship was financial. While I could find work at a strawberry farm, a chocolate factory, online tutoring, and several other odd jobs, money was always a concern. The pandemic made it especially difficult to find an internship, which is a core part of our program and a primary reason why I chose the program in the first place. Originally I had planned to go to India in June 2020.

This would have been paid as it was overseas. But being unable to go overseas meant that I needed to find an online one or one within Finland. The problem with needing to find an education internship within Finland is that mastery of the Finnish language is often a prerequisite.

Another problem is that, mostly, they are unpaid. This was a massive problem for me as I had factored into my finances pre-application that I would be getting paid for my internship. Ultimately I was left to complete my internship online and unpaid. At the same time, I was writing my thesis and working part-time.

A further complication was the fact that I needed to complete it before the July 31 deadline. This period was tumultuous for me. I was unable to complete my thesis the way I wanted to; instead just submitting for the sake of submitting.

By the end, I was completely run down and my mental health had suffered severely. I was in a foreign country without any financial or familial support, unable to return to my own country due to border closures. However, I was very grateful that my faculty permitted me a 3-months exception to resubmit my thesis."

Story 4: This story is one of the participants' personal experiences, which talks about the immigration issues and getting a resident permit. It was selected since the volunteer uttered the hardship story about the university.

"While my husband was a staff member of the University of Oulu, I was waiting so long for the final decision on my resident permit, which lasted two years! The university did not support my husband and me in this matter.

They even did not bother themselves to contact the immigration service and follow up on the permit application. At the same time, we were under severe mental pressure while seeing others can enter Finland without any problem, and their decisions were made in less than a month.

My husband could not focus on his studies and tasks because he had to focus on writing requests to the immigration service. In the end, my decision was released without any interference from the university. So there's no support for their employees."

Story 5: This story combined two stories that describe many critical issues, such as social problems and cultural barriers. These stories bring personal examples regarding the topics that talk.

"Cultural barriers are very big for non-natives. Becoming friends with Finnish people is very difficult unless you are willing to make an effort and have a lot of patience. There have been times in which people have treated me differently because I am a foreigner.

Sometimes happens that the bus is crowded, and people sit next to each other, but no one tries to sit close to me. Even when I can not find two empty seats next to each other, I prefer to stand up and not sit next to other.

I have been actively excluded from work conversations by having people in a group suddenly switch to Finnish. This has caused a lot of anxiety to me that I have had to cope with through psychotherapy."

4. THE VR EXPERIMENT

In this chapter, we explain the procedure and main concepts of the design and implementation of the VR experiment. The first section of this chapter reviews all the necessary hardware and software setups to build this project. Then, the second section of the chapter explains the project's design as a VR application. After that, we go through the implementation of each part of the project in more detail. Finally, we present the experiment design.

4.1. Implementation Setup

As the first step of the development, it is required to define our technical setup and how they work. It is because setting up all of this software and hardware enabled us to start the project's development. The setup includes the engine, VR device and related applications, project settings, plugins, and package setups, in addition to the hardware specification introduction.

4.1.1. Engine Setup: Unity

One of the essential decisions during the early stages of the development was to choose proper development tools based on needs and the project's requirements. Due to the application and purpose of the project, and since we developed a 3D VR application based on the University environment model, employing a suitable graphical engine as the basement of the development was prominent for us. Before starting the project development, we knew the project would be similar to a 3D game.

Therefore, we had to handle many technical aspects analogous to a 3D video game. For instance, all the communications among the project's components should be synchronized, player controls, character animations, physics, collisions, and many other significant issues should be handled perfectly to let the application works smoothly.

We selected the Unity engine as our primary development tool and graphical engine due to the argument explored in the Background chapter, Section 2.2.1. Thanks to Unity Technologies, setting up the engine was straightforward. First, we installed *Unity Hub* version 3.1.2. Unity Hub is a project manager and launcher tool for the Unity engine. We could create or add our project with this tool and manage to employ which version of the engine to launch and develop the project. With Unity Hub, we could also access distinct versions of the engine to install, developers' community, and learning tutorials.

Furthermore, we installed the engine through Unity Hub by selecting *Installs* to see all official and pre-release versions. We chose Unity engine version 2021.1.16f1, the latest official release. During the installing process, we chose our desired SDKs, such as relevant files for the Windows and Android platforms, in addition to *Visual Studio* software. After that, this engine version was accessible within the Unity Hub to create and open a new project with it.

4.1.2. HMD Device Setup: Oculus Quest 2

Setting up the HMD device was an essential step toward initializing the implementation since the project was aimed to be a VR application. Also, we needed to set up the HMD device to test the project during development since it was vital to investigate all designed and implemented parts of the project in VR, not on a desktop device. As discussed in Section 6.3, there are many related design issues in VR that we could only assess or realize when we test the application in VR. Therefore, we provided the opportunity to test the project without building it every time since it would be time-consuming.

Oculus Quest 2 was selected as our HMD device for development for several reasons, such as its rich documentation and developers' community, as discussed in Section 2.2.1. So, two software applications, namely *Oculus*, had to be installed to set up the Quest 2 device. One Oculus application was for the mobile phone to let the device initiate to work. The other Oculus application was for Windows, allowing the device to connect to a PC. Developer mode had to be activated in the applications to run our project on the device without building.

Furthermore, we connected our PC and HMD devices to one private network to connect them with *AirLink*. AirLink is the newest approach to connecting an Oculus HMD device to a PC to stream all contents from the PC to the HMD device with the highest quality [87]. After establishing this connection, Quest 2 launched and streamed the Unity engine from our PC. Therefore, whenever we wanted to assess our development, we played the project in the engine's editor mode, which means the application did not require to be built.

4.1.3. Project Setup

After setting up the engine and the HMD device, we set up the project to begin the implementation. Setting up a Unity project may require installing more packages, and plug-ins than the default projects template have. So, in this section, we also introduce the packages and plug-ins we installed to develop our VR project.

To begin, we created the project from a basic 3D project template from Unity Hub after selecting the current version of the installed engine. In the project's settings, it was required to install *XR Plug-in Management*, which is a package for XR plug-ins management, initializing, and build support [117]. In XR Plug-in Management, there were several options such as Oculus, *Open XR*, and *Unity Mock HMD*. We continued with Open XR since it translates and supports all different HMD devices and controllers, including Oculus as a standardized package.

Furthermore, in the Open XR tab in the project setting, we defined our interaction profile for the engine. It means we needed to determine what type of HMD devices we planned to employ for the engine. We added *Oculus Touch Controller Profile* in the interaction profiles, which means we would like to use the Oculus input and controllers system. We also changed the render mode to *Multi Pass* which means the engine rendered the application for each eye in the HMD separately to provide a better VR experience.

Likewise, to let the engine be able to translate the inputs from the HMD device to a recognizable action in the application, we installed *XR Interaction Toolkit* from the engine's package manager. This package also contained several scripted input actions, namely *Default Input Actions* which let us define and employ the input actions immediately. We described our input action for controllers, movement, and turning by importing the package and its examples. In Section 4.3.4, we explain the implementation of continuous movement and turn in more detail.

We defined all the pre-configured and scripted input actions as the default input action by adding the scripts to the project setting's preset manager to finalize the project setup. In the preset manager, we added right and left controllers too.

Finally, we added the project's path as a new repository to *GitHub* to initiate our version control, letting us keep track of the development straightforwardly. The repository of the project is titled as *Situated-Empathy-in-VR* and available here.

4.1.4. Hardware Specification

In addition to the software and HMD setups and details that are introduced in previous subsections, here we present our hardware configuration. To perform all mentioned software and applications, we employed a Lenovo ThinkPad T15G Gen 1 with system model 20UR0039MX. It was enhanced with an Intel(R) Core(TM) i7−10750H CPU with 6 Cores and 12 Logical Processors and had 32 GB RAM. It was also powered with an NVIDIA GeForce RTX 2080 Super with Max−Q Design.

4.2. Scene Design

After setting up the project and all related required software and hardware, we explain the design of the scene based on our study purpose in this section. Scene design means creating and maintaining a clear idea of what we would like to implement before the actual implementation starts. Also, it was done based on all we had on the table, such as the study's purpose, available software, hardware, project setup, discussed ideas, etc.

Based on our setup and ideas for the project, we had the design of the scene as a big picture first. Then we implemented the project to get closer to the big picture as much as possible. The scene contained a virtual environment of the University of Oulu, thanks to Dr. Pouke, as the basement of the whole project. Then, we placed several avatars accordingly close together in a specific part of the environment to make it simple for participants to find the avatars and do the experiment.

This approach also helped us when designing a crowd in the environment. Since the virtual environment was the university environment, we required developing and implementing several random characters as the crowd at the university for the environment. The crowd helped participants feel that they were at the university.

The university's central corridor and the L1 lecture room were selected as the virtual environment where all the experiments happened virtually. As we explain later in Section 4.3.6, we employed and implemented several ideas to direct participants to stay in the selected places.

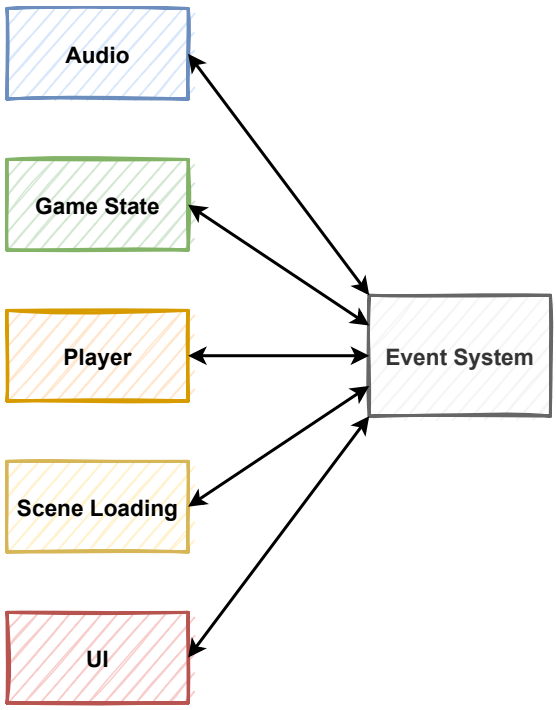

Figure 14. An overview of how an event system manages events among distinct parts of the application.

4.3. Technical Implementation

In this section, we explain all details regarding the implementation of the project from a technical point of view. In each subsection, we go through a distinct part of the whole implementation in addition to their definitions, roles, and implementations.

4.3.1. Event System

We defined the event system as an abstract game object in the hierarchy of a Unity project. We employed the event system in the project to handle the events, such as sending events based on the input system to the game objects. This system enhanced the project's performance since it managed all the events that occur among different parts of the project, such as the user interface system. As shown in Fig 14, game objects do not require sending the events and communicate directly to each other by employing the event system.

Also, we used this system to manage and update the input module, which was *XR UI Input Module* in our project. XR UI Input Module is a base class that is written in XR Interaction Toolkit for the input module to send and handle the UI input for all HMD devices in addition to other input systems, such as mouse input, keyboard input, etc. So, XR UI Input Module is added as a component to the event system with a configuration for Click Speed, Repeat Delay, Repeat Rate, etc. to have a suitable input system for HMD devices and manage the events' states. The configuration was prefilled based on the XR UI Input Module script.

We explain in detail in the further sections that the UI system in a VR application requires a graphic raycaster to make players able to work with the controllers and the UI. Therefore, the event system in our project managed these raycasters.

4.3.2. XR Origin

XR Origin was a game object that defined the HMD and controller as objects in the engine for the application and virtual environment. XR Origin was described for the VR project as the same as *Player* is defined for the engine. After completing the project setup, we added this game object to the project hierarchy. Then, XR Origin was the entire setup as the Player for the engine. It also helped the engine handle physics for the Player in VR, as we explain further in Section 4.3.5.

XR Origin contained *Camera Offset* which was an abstract game object in the project hierarchy and was updated during the experience by the HMD device and controllers. Camera Offset had the *Main Camera* game object, which showed the scene to participants and had a component as *Audio Listener*. Audio Listener allowed participants to hear all the sounds in the environment. The primary camera also had an attached pre-written script as *Tracked Pose Driver (Input System)*, which tracked and updated the rotation and position of participants.

Furthermore, Camera Offset contained two game objects as *LeftHand Controller* and *RightHand Controller*, including all pre-configured scripts and models for virtual hands. These controllers contained a script, namely *XR Controller (Action-based)* from XR Interaction Toolkit to define all the actions. They also had *XR Ray Interactor*, *Line Renderer*, and *XR Interactor Line Visual* scripts to render and show visible lines from virtual hands and define the interactions among them and the environment.

4.3.3. XR Interaction Manager

XR Interaction Manager was a game object created in the project by adding XR Origin to the project hierarchy and was from XR Interaction Toolkit. This object managed input action via *XRI Default Input Actions* script, which was included in XR Interaction Toolkit.

4.3.4. Locomotion System

We defined and implemented the locomotion in the project to let participants be able to move around, rotate, and turn freely in the virtual environment. For this purpose, thank to XR Interaction Toolkit, we created and added an abstract game object, namely *Locomotion System (Action-based)* to the project hierarchy. This game object included all the necessary scripts to convert participants' inputs to a proper movement, rotation, and turning. These scripts were all pre-configured for the movement and rotation speed, which were 1 and 60, respectively. We defined our XR Origin object for the Locomotion System to finalize the configuration.

Since our project environment was a simulation of the university environment, we provided realistic movement and rotation for the application. To this end, we employed two scripts from XR Interaction Toolkit, which were *Continuous Move Provider (Action-based)* and *Continuous Turn Provider (Action-based)* to let participants move and turn continuously, which was more naturalistic.

As mainly developers in VR applications do, we employed the right controller for turning and the left controller for movement. In the mentioned scripts for movement and turning, we defined the suitable controller for each. Therefore, we used the right controller's reference in the movement script and did the same for the left controller in the script for turning. Then, participants used the right controller's thumbstick for turning and the left controller's thumbstick to move in any direction.

4.3.5. Physics and Collisions

We handled the collision between the player character, the XR Origin, and other game objects in the university model to make the interaction realistic among them. We defined how they collide to avoid any undesired situation, such as passing through the walls, doors, and pillars during the experience. The XR Origin had a realistic collision with objects in the virtual environment, and it could not pass through them as it is impossible for a person in the real world.

For this purpose, we defined proper physic and collision for all the game objects in the environment, which was *Mesh Collider*. Mesh Collider is a component in the Unity engine and could be added to each game object we would like. Therefore, we defined Mesh Collider for all the game objects that we did not want the XR Origin to pass through them, such as all the university model game objects such as grounds, walls, pillars, stairs, etc. Mesh Collider makes a collider based on the game object's mesh which means the collider covers all the surfaces of the game object perfectly.

We also defined a component for the XR Origin, namely *Character Controller*. This component added accurate physic to the XR Origin for two purposes. First, it made a configurable *Capsule Collider* for the XR Origin that allowed it to collide with any other game objects that had Mesh Collider and did not pass through it. Secondly, with the Character Controller, we defined the XR Origin would be able to move on surfaces with slopes and jump on small objects as we configured.

We modified the radius of the capsule collider to 0.25 to let it had the same width as a human in the environment. Also, we defined its center as 0.5 to be higher than the floor to avoid being stuck in the ground's Mesh Collider. As mentioned earlier, the Character Controller component had options to configure that the XR Origin would be able to climb from the objects.

Since the virtual university environment had staircases in the main corridor and the L1 lecture room, we adjusted *Slope Limit* to 45 degrees and *Step Offset* to 0.15 to let the XR Origin be able to climb the stairs. Slope Limit defined that the character was able to move on a surface with a 45-degree slope. Step Offset represented that the Character Controller could walk on the game objects with a height lower than its value. Therefore, with these pre-set options, the XR Origin could walk up the stairs in the environment.

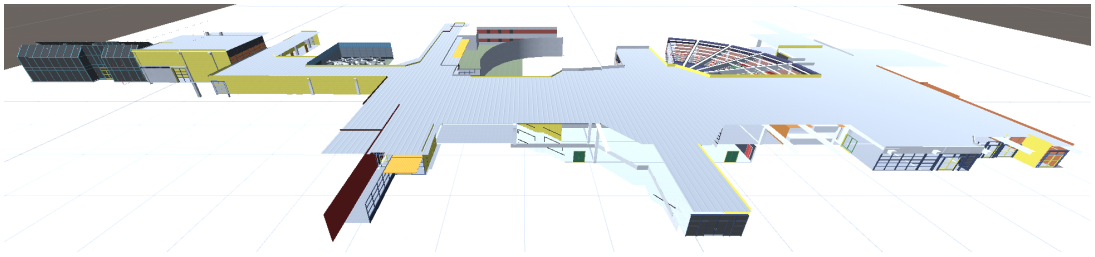

Figure 15. An overview of the university model, which is placed on the plane in the scene.

4.3.6. University Environment Implementation

To implement the virtual environment of the university in the engine, first, we created a folder, namely *University Models*, then imported the university model *Filmbox (FBX)* file to the engine. FBX is a file format that supports 3D models, scene hierarchy, materials lighting, etc. and is employed in the Unity engine to store 3D models and scenes [118]. After that, from the inspector of the models, we extracted the model's textures and materials to new folders, namely *Textures* and *Materials* in the assets folder of the project respectively. Since the university model had many distinct objects, having two separate folders for textures and materials made them more accessible for any possible modification.

The university model had all its textures and materials in the engine. Therefore, we dragged and dropped the model to the scene to develop. However, before that, we created a *Plane* game object like a floor for the whole parts of the model. A plane is a game object primarily used as the ground in a Unity project. Finally, the university model was placed on the plane, as indicated in Fig 15.

Furthermore, as explained in previous sections, We only needed the main corridor of the university and the L1 lecture room for the experiment. Therefore, we designed and placed several game objects to limit the university's map that the participants could explore during the experiment since the university model was enormous for our purpose. We called these game objects as *Blocking Objects* in the engine since they were supposed to stop participants from getting away from the defined places. In the rest of this section, we explain the design and implementation of these objects.

Blocking Objects

As explained earlier, the purpose of the design and placing of these objects was to limit the places that participants could explore during the experiment. To this end, first, we created an empty game object in the project hierarchy and named it *Blocking Objects* to group all these objects in the engine. Secondly, we created four cubes and placed two at the end of the main corridor and two at the main lobby to close the hall from all four exits.

Since two of them were far enough from the place that all avatars were supposed to be, we unchecked their *Mesh Renderer* components to make them invisible to participants. Mesh Renderer is a game object component that lets the engine render the game object's mesh and materials. Since these cubes still had their colliders, the XR Origin could not pass through them, as Section 4.3.5 explains.

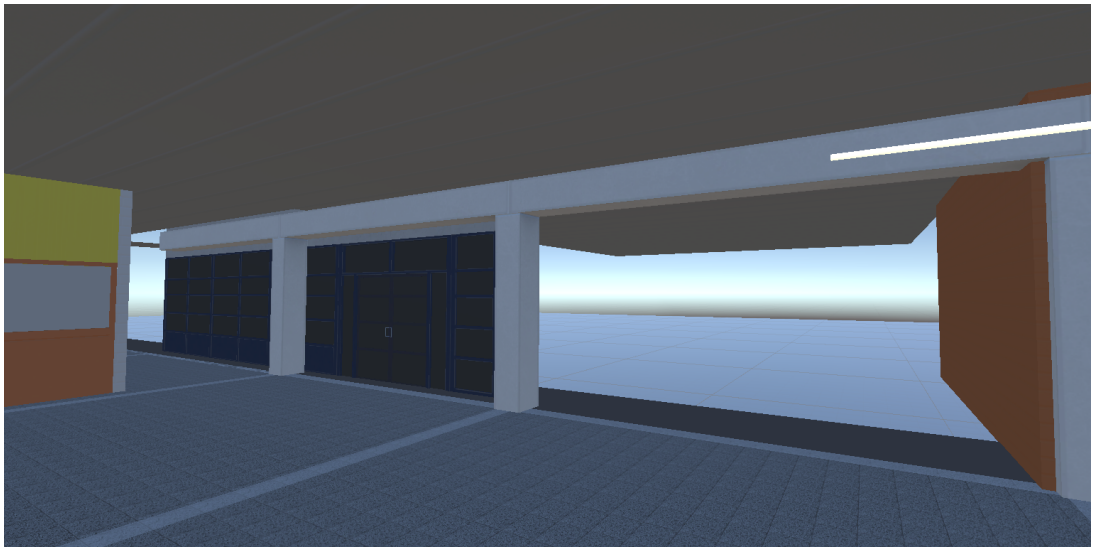

Figure 16. The main corridor of the university model in the scene without Sprites.

Two Blocking Objects were in the same place as the avatars were. So, as shown in Fig 16, if we also made them invisible to participants, outside of the university model would be visible to participants that were not designed to be, such as the plane. For this purpose, we placed two images on these two objects to be supposed as banners in the virtual environment. These objects were still limiting the environment since they also had colliders. However, the only difference was that we also defined one more feature to let us place images on them. We explain it in the following section.

Sprite Holders

So, we let two Blocking Objects hold images as banners. For this purpose, first, we created an empty game object as a child for each of the Blocking Objects and named them as *Sprite Holder 1* and *Sprite Holder 2*. Since these new objects were a child of the Blocking Objects, their positions were accordingly set to their parents' positions. We created a new component for both new objects titled as *Sprite Renderer*. *Sprite* is a texture type and means as a 2D and UI element to the engine. Sprite Renderer gets a Sprite and represents it with a configurable specification in the scene. This component had many options, but we only assigned our image as a new Sprite.

We imported our images to the engine to a new folder in assets, namely *Images*. These images converted their texture type to Sprite to be able to be assigned to a Sprite Renderer. To this end, we converted their texture type via the engine with the basic configuration such as 100 pixels per unit. Finally, the images were assigned to the Sprite Holders' Sprite Renderers and worked as banners in the scene, as represented in Fig 17. It should be mentioned that the pictures are our posters for this study's demo paper [29] and were designed by ourselves.

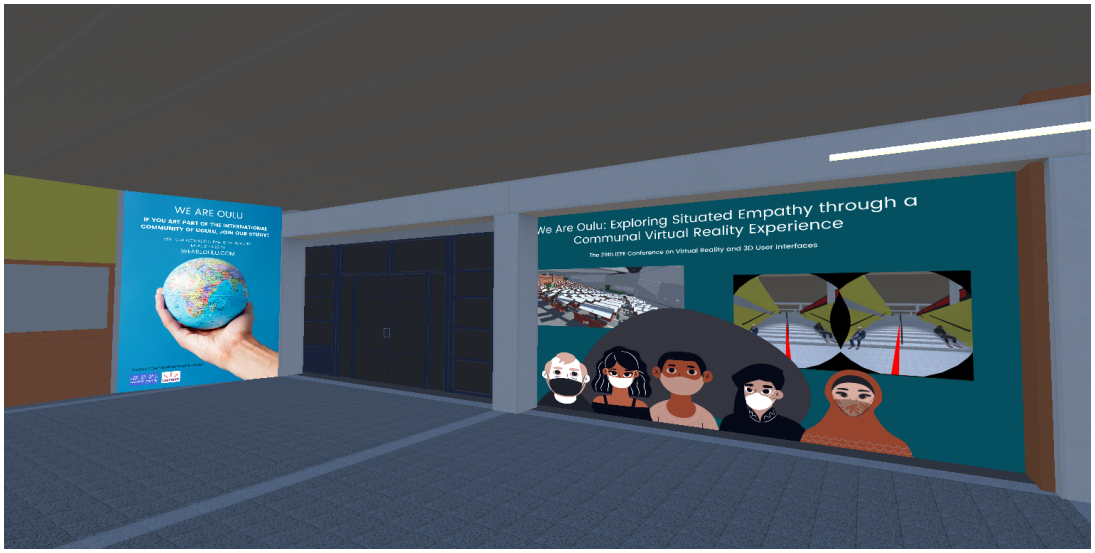

Figure 17. The main corridor of the university model in the scene with Sprites as banners in the environment.

4.3.7. Lighting System

The lighting system in this project was divided into two primary parts: *Exterior Lighting* and *Interior Lighting*. This section explains these two lighting systems separately.

Directional Light

For the exterior lighting, we employed *Directional Light*, which is the primary approach of the Unity engine for illumination. Directional Light is a game object in the project hierarchy and is one of the types of light objects in this category. Directional Light has several options in its inspector, such as *Intensity* which sets the intensity of light radiation. We put it as the default value, which is 1.

We also set the shadow type that this light could produce as *Soft Shadows*, which means if this light hit a non-transparent object, the engine would render a soft shadow based on the light's direction. This light was used to supply the overall lighting in the project. Otherwise, nothing could be seen clearly after building the project.

Interior Lighting

To optimize the application's performance, we employed an ordinary game object rather than a type of light for the interior lighting, namely a *Cylinder* game object. The only difference that these objects had in the project was their material. We set an option in their materials, namely *Emission*. This option caused the objects to reflect the Directional Light more than other objects in the environment.

Therefore, objects with emission material seemed to shine similar to lights, but they did not produce any light. This technique helped us not to employ extra lights and increased the application's performance since lights are bottlenecks for the engine's performance [119]. As shown in Fig 18, the virtual environment's interior lighting was designed similar to the real environment of the university.

Figure 18. Interior lighting of the university L1 lecture room in the scene with Emission.

4.3.8. Sound and Audio

In this project, we used audio for the crowd's sound to increase the immersion of the experience. The crowd's sound helped participants feel more that they were in the university environment. Participants heard an actual recorded sound at a university campus while seeing many students and people in the virtual environment.

First, to implement the crowd sound, we created an empty game object in the project's hierarchy and named it *University Crowd Sound*. Then we adjusted the position of this game object accordingly to the place that the crowd was designed and placed. We added the *Audio Source* as a new component to the game object. The audio source is a prefabricated component in the Unity engine to let a game object has sound. This component has a global field titled *AudioClip*. As the field's name says, we attached our desired audio clip to the game object as the crowd's sound. We employed a free-to-download university ambient sound, namely *University Ambience 3* from the *QuickSounds.com* website.

The audio source component had many features and options that allowed us to modify the sound ideally. We checked both *Play On Awake* and *Loop* options to make the engine played the sound clip in the first frame whenever the application was started and repeated the sound until the application was stopped, respectively. Since there was no other audio source in the environment, the *Priority* feature was not essential for us. This feature allows players to hear a sound first or in a higher priority in comparison to other audio sources. We also adjusted the volume's value to 0.5 out of 1 to attune the sound to the crowd.

Since the project was a 3D application, we converted the crowd's sound into a 3D sound to let participants hear the sound according to their distance and positions from the crowd in the environment. To this end, there was an option, namely *Spatial Blend* that made the audio source a 2D or 3D sound. We set it to 1, which meant to the engine that the audio source was a 3D sound. Additionally, we modified another feature here, titled as *Volume Rolloff* to be *Linear Rolloff*. Volume Rolloff determined how the engine had to increase and decrease the sound based on the participants' distance from

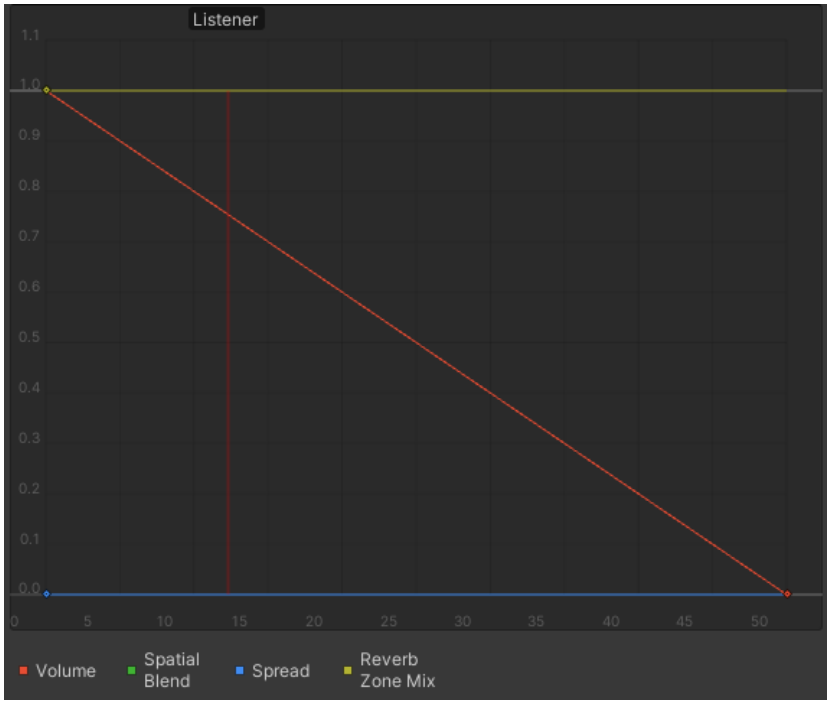

Figure 19. An overview of the audio source chart when a listener is at a distance of around 15 with it.

the crowd. We set it to Linear Rolloff since it changed the volume linearly. Then the changes in the sound's volume were evident in a 3D environment.

As indicated in Fig 19, the volume of the sound changed from its highest amount to the lowest linearly based on the distance to the *Listener* as we explained. A listener is a game object that is able to hear the audio source. In our project, the listener was the participant, which technically was the XR Origin, particularly the camera. Since the crowd sound spread in all directions in a sphere shape, *Spread* was set as 0. Since we did not change the audio source from one to another and the listener could hear the audio source all the time in the environment, *Reverb Zone Mix* was set as 1. Reverb Zone Mix adjusts the amount of the audio source's output signal based on the listener's reverb zone.

Finally, there were the minimum and maximum distances for the audio source, as demonstrated in Fig 19. They mean that the audio source is valid and can be heard whenever the listener is not closer than the minimum distance and is no farther than the maximum distance. In the project, since the sound was supposed as a crowd's sound, the minimum distance was 0.001, to be impossible to get close enough to the audio source. The maximum distance was 50 to cover a reasonable area near the crowd.

4.3.9. Dialogue System

In this section, we explain *Dialogue System* that allowed participants to have a short conversation with avatars in the virtual environment and read the stories we prepared for the experiment. Our Dialogue System contained two main parts, namely *Dialogue*

Figure 20. An example of how the Dialogue System works to show stories to participants.

Manager and *Dialogue Database* to perform the conversations and store the stories related to each avatar (conversant), respectively.

We employed a pre-made asset, namely *Dialogue System for Unity* created by *Pixel Crushers* to accelerate our implementation. This system contained vast options to handle and perform the conversations in Unity.

Dialogue Manager

Adding the Dialogue System asset to the engine enabled us to create the Dialogue Manager game object in the project hierarchy. This game object had a component titled *Dialogue System Controller* which contained all the settings to complete a dialogue system we would like to employ for the application, such as showing conversants' names, typing stories speed, etc. In this component, we could define and link a database for the conversation, conversants, and actors. We talk more about the database in the following subsection.

The Dialogue System asset contained several Graphical User Interface (GUI) templates for the dialogues. We selected and assigned one of the templates, namely *Nuke Standard Dialogue UI* in the Dialogue System Controller component. Since this template had a dark transparent background with distinguished text color, it was a good choice, as we explain in Section 6.3. As shown in Fig 20, avatars' dialogues were illustrated beside avatars related to participants' current position. There was also a *Continue* button in the GUI to let participants read the stories calmly and go to the following conversation by their choices.

There was another component in Dialogue Manager, namely *Input Device Manager* which handled the input system that participants could use to interact with the dialogues. We defined *Joystick* as our input device since participants employed controllers in our application.

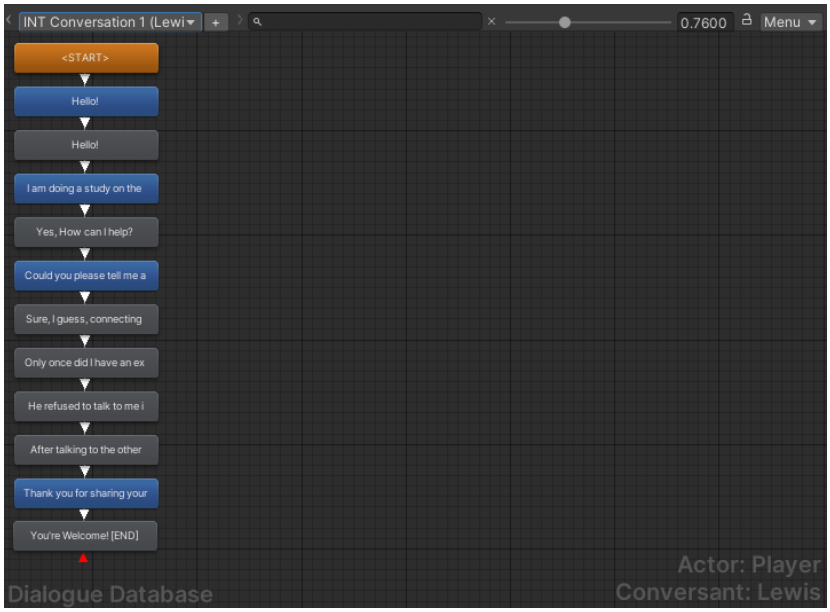

Figure 21. An example of a stored and assigned conversation in the Dialogue Database.

Dialogue Database

From the Dialogue Manager game object, Dialogue System Controller, we created a Dialogue Database to assign and store our avatars as conversants and the stories and conversations as state machines. The database allowed the Dialogue Manager knew the avatars by name since each avatar was assigned as a conversant. Also, the storage model for the conversations as a state machine helped the Dialogue Manager perform the conversations in a specific order.

As indicated in Fig 21, a conversation was assigned to a conversant, which was one of the avatars. When the Dialogue Manager performed this conversation, it started from the first state, which was the *<START>* state, and continued to the last state, which was labeled as *[END]*. We assigned each conversation state to perform as a dialogue from participants or avatars by labeling them as a blue state for participants and a gray state for avatars.

4.3.10. Non-Playable Characters

As we claimed earlier, one of the essential parts of the implementation was to have virtual characters to let the participants have a conversation with them. Also, we needed several other non-playable characters (NPC, also defined as Non-Player Character) as the crowd in the virtual environment to allow us to simulate the Univesity's atmosphere, as shown in Fig 22. To this end, first, we generated and downloaded our NPCs' 3D models and animations as Binary FBX files with optimized textures and skins for Unity with the *Mixamo* website.

Therefore, we randomly put several 3D female and male models with assigned animation in the environment as the crowd, namely as *Non-Interactable Characters* game objects in the engine. Also, we had five models as our interactable avatars in the environment with more specific setups and components. As explained in Section 4.3.5,

Figure 22. An example of NPCs with interactable and non-interactable characters.

we added a Character Controller component to add proper physic to avatars. Even, we added a component, namely *Dialogue System Trigger* from the dialogue system to assign a story from the database to avatars by defining XR Origin as the actor and one of the conversants' names in the database as the conversant. This component had a trigger function that initiated the conversation when it would be called.

We defined and added two scripts as components to interactable characters or, let us say, the avatars who described the stories, namely *Usable* and *Move Dialogue Panel*. The Usable script defined the assigned NPC as a valid object to interact with the input system at a specific distance. The other script moved the dialogue panel and NPC to the participant's position to let the participant and NPC talk face to face.

4.3.11. Animation

We worked with the engine's animation system for two purposes in our project. First, NPCs required proper animations when they were idle (for both interactable and non-interactable characters) and when they had a conversation with participants (for only interactable characters). Secondly, the virtual hands of participants in the application needed two animations for griping and closing hands.

Implementing animation for NPCs was straightforward since we downloaded small 30 frame rates idle, walk, talk, etc., animation files for 3D models from Mixamo during 3D model generation. We defined a component for each NPC, namely *Animator*, which was an interface to control and modify the animation for the assigned game object. Animator has a *Controller* variable to link the component to *Animator Controller*, which is a finite state machine to move the game object from a state with a specific animation to another state with another animation based on a defined trigger.

Therefore, we created an Animator Controller for each NPC depending on what states it required. For interactable NPCs, we defined four primary states: *Entry*, *Idle*, *Talking*, and *Exit*. We defined a trigger variable, namely *IsTalking* which become *True*

when participants initiated the conversation with an avatar, as we explain in more detail in Section 4.3.12. This trigger caused the avatar's Animator Controller moved from the Idle state to the Talking state. Animator Controller worked pretty similarly for non-interactable NPCs, except it did not have the Talking state.

The animation system worked similarly for the virtual hands. Each controller in the engine was assigned to an Oculus hand model that we downloaded from Oculus's website freely. So, we created avatars from the models for each hand. Then, we made an animation clip based on the primary hand model in the engine's animation system to show the hand gripping and closing gestures. The animation clip showed the hand in a closing gesture. However, by employing a feature in the engine, namely *Avatar Mask*, we could create a mask for each motion and select the parts of the hand that we would like to move.

We created an Animator Controller with one state for the standard hand gesture, and another state for whenever gripping or closing motions were called based on their triggers. We defined an Animator for each hand model to assign the Animator Controller. We implemented a script, namely *Hand* and attached it to both hand models. This script managed gripping, closing, animating, etc., that the hand model could do. Then, we implemented another script, namely *Hand Controller* and assigned it to both controllers to trigger those actions based on the input we defined. For instance, we employed *Secondary Trigger Button* to close the hand (Fisting).

4.3.12. User Interface

We created a User Interface (UI) system with the engine to allow participants to interact with avatars in the environment during the experience smoothly. The UI system helped participants find interactive avatars first, have a written conversation and read the stories. Therefore, we created a button for interactive characters from the list of UI game objects of the engine and called it *TALK*, as indicated in Fig 20 and Fig 22. We put these buttons on top of the avatars to allow participants to find interactive characters during the experiment fast and then initiate the conversation.

We added a component to buttons, namely *Button* to let us configure them, such as specifying their colors when buttons are pressed or selected. Additionally, we configured the interactable buttons and defined the events on them to be activated after pressing. Therefore, for each button, we implemented two event function, namely *OnClick()*, which were active during runtime. So, whenever participants pressed one of the buttons, the pressed button called its event functions immediately. The first event function called *DialogueSystemTrigger()* function to run and started the avatar's dialogue box to initiate the conversation. The second event function called *Animator.SetTrigger()* function to run the avatar's animator to perform the assigned animation to the event.

In the Unity engine, to be able to use its UI features, we created a UI game object, namely *Canvas*. Canvas is a game object that maintains UI elements as its children in the engine [120]. Consequently, we created and assigned a Canvas for each avatar's TALK button. Since our project was a VR application, we set the Canvas' render mode as *World Space*. This render mode made the UI element fixed in the environment. So,

UI elements such as the dialogue box did not follow the camera since it could be annoying in VR.

We defined two components for each Canvas, namely *Graphic Raycaster* and *Tracked Device Graphic Raycaster* to let it be identifiable for controllers and input system. Then, participants were able to click on the buttons.

4.4. Experiment Design

This section presents our VR experiment design for the implemented study. We explain an overview of the experiment and our setup first. Then, we introduce the pre- and post-experiment questionnaires we employed in the experiment. Finally, we present the follow-up semi-structured interview of the experiment.

4.4.1. Experiment Overview and Setup

After concluding the implementation, we arranged to perform the VR experiment as a 45 to 60 minutes study on-site at TS365 (XR Lab), Ubicomp Center, Linnanmaa campus of the University of Oulu. Therefore, we prepared the experiment technical setup and designed the flow, as explained in the rest of this section.

As the technical setup for the experiment, we employed the same PC device and Unity engine version we used for the implementation to run the VR application. Also, we used an Oculus Quest 2 device as the VR headset. Furthermore, we established a local network to connect the PC with the VR headset to run the VR application on the PC and stream the content to the VR headset with AirLink [87], as explained earlier for the implementation.

The VR experiment had three main steps to be done in each session. In the first step, after a participant came to the lab, the thesis's author, the responsible researcher, and one of his colleagues invited them to sit in the specified place. The thesis's author briefly introduced himself and his colleague, the study, and the experiment steps to the participant. Then, the participant was asked to complete the pre-experiment questionnaire through an online survey via the PC, as shown in Fig 23. This step took about 15 minutes of the session.

In the next step of the experiment, we asked the participant to read a brief instruction that was prepared about the VR experiment. The instruction explained the task: of finding and visiting five virtual avatars in the university's virtual environment. It also contained information about how participants should work with the VR headset and controllers, how to move in the virtual environment, and how to have a virtual conversation with avatars. Then, we asked the participant to be in the specified place and perform the VR application, as shown in Fig 24. This step also took about 15 minutes of the session. After the participant had done the task, we asked them about their overall feeling and physical condition to understand whether they had motion sickness or dizziness or not.

As the last step of the experiment session, the participant was asked to complete the post-experiment questionnaire through an online survey via the PC. After that, the researchers performed a follow-up semi-structured interview with the participant.

Figure 23. An example of the experiment setup and a participant that is completing the experiment questionnaires.

This step took about 15 to 30 minutes of the session. Finally, the participant got compensated with a 10 euros gift card for their time and contribution at the end of the experiment session. The researchers created a checklist of the explained flow to repeat the same procedure with every participant in each session.

4.4.2. Experiment Questionnaires

We developed a pre- and post-experiment questionnaire in Google Forms for the VR experiment to collect the required data from participants during the experiment.

Filling out the pre-experiment questionnaire was the first task we asked our participants to do during the experiment sessions. Our pre-experiment questionnaire contains three main sections. In the first section, we placed a consent form that contained general information about the research and the collected research data, safety precautions for COVID-19, data archiving, and the rights of the subject. Also, we put complete contact information about the researchers and the principal investigator at the

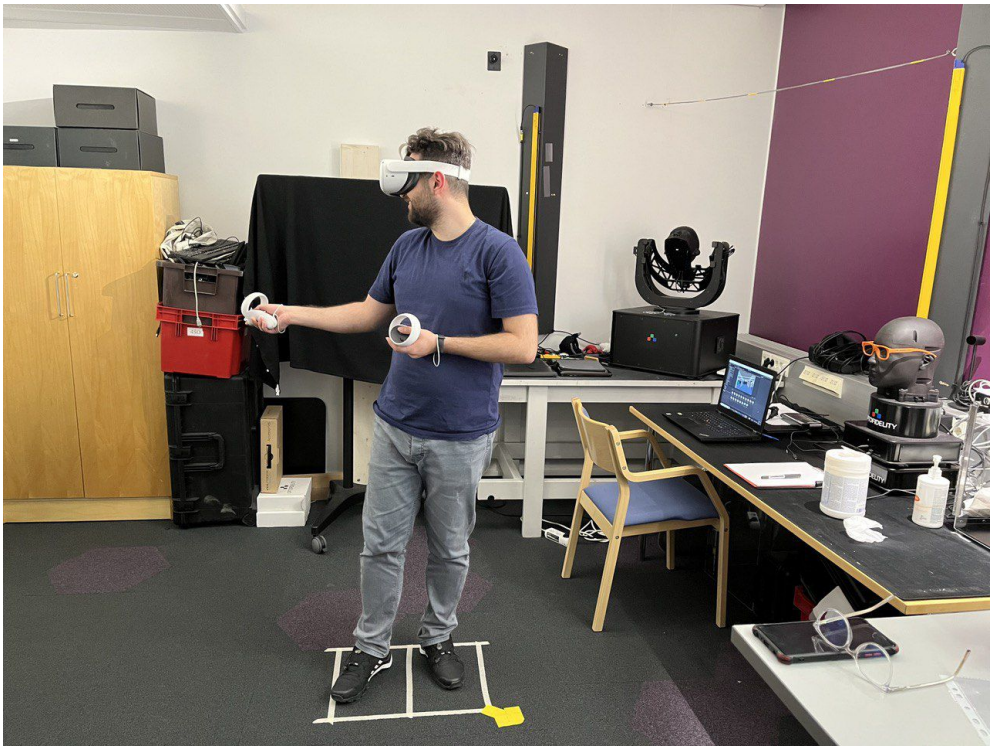

Figure 24. An example of the experiment setup and a participant that is performing the VR experiment.

end of the consent form. Then, participants checked the answer as *I confirm and sign* as signing the consent form to be able to proceed to the next section of the questionnaire.

In the next section of the pre-experiment questionnaire, we asked two questions about their knowledge and experience in discussing the international community's hardships on a 5-point Likert scale of 1 (*Not at all much*) to 5 (*Extremely much*). These questions are questions 1 and 2 in Table 1. Also, we asked about their awareness of the international community's quality of life on a 7-point Likert scale of 1 (*Their QoL is a lot worse*) to 7 (*Their QoL is a lot better*). It is question 3 in Table 1.

These three questions related to the international community's hardships were also asked again after the VR experiment in the post-experiment questionnaire. These questions are presented in Table 1 as in the way they were asked in both questionnaires.

Table 1. The hardship-related questions in the pre- and post-experiment questionnaires.

	Questions
Pre-experiment	1. How much do you know about the hardships faced by the international community in Finland? 2. Have you ever talked with someone about any hardships that the international communities face in Finland? 3. How do you evaluate the international community's quality of life in comparison with yourself?
Post-experiment	1. After the experiment, now how much do you know about the hardships faced by the international community in Finland? 2. Would you like to talk with someone, such as your friends or even other international people about the hardships that the international communities face in Finland? 3. How do you evaluate the international community's quality of life in comparison with yourself?

The post-experiment questionnaire only contained these three questions that we asked to fill out after ensuring participants had no sickness and dizziness after the VR experiment.

Also, we asked for participants' demographic and background information in the pre-experiment questionnaire. We asked about their gender, age, nationality (as Finnish native, half from mother or father, and not Finnish native), and current status regarding Finland's higher education system.

The last section of the pre-experiment questionnaire is designed to ask the QCAE questions. As we describe in Chapter 2, Reniers et al. [32] developed The QCAE - Questionnaire of Cognitive and Affective Empathy to measure the total empathy scores based on the subject's cognitive and affective empathy scores. The QCAE has 31 established and validated questions on a 4-point Likert scale of 1 (*Strongly Disagree*) to 4 (*Strongly Agree*). Consequently, we created its questions in the last section of the pre-experiment questionnaire.

4.4.3. Experiment Interview

As the last step of the experiment, we had a post-experiment semi-structured interview to ask our experiment's participants in-depth reflections on several open-ended questions. The interview with participants started when they finished filling out the post-experiment questionnaire with a short explanation about the study and its objectives by the interviewer. The author of the thesis designed the interview template in order to have the same flow and questions during the interviews with participants in four main sections. Topics of each section and its related questions are as follows:

Section I: The VR Experience and Experiment: This section's questions asked participants to reflect on their experiences during the VR experiment and the VR application.

1. *What were your first impressions of the experiment?*
2. *Was the VR experience believable? Did you feel like you were in the campus area?*
3. *In your opinion, did the VR experience do what it was designed to do?*
4. *What should be changed or revised in the experiment?*

Section II: Reflection on the Stories: In this section, we asked participants to elaborate on the stories they read during the experiment.

1. *Which one of the avatars' stories do you remember most clearly? Why?*
2. *Did the stories include information that was new to you?*
3. *What did you think about the stories in general? Did the experience feel like you were hearing stories told by real people?*

Section III: Influence on Empathy: This section asked participants to reflect on their situated empathy regarding the hardships of the international community of the University of Oulu.

1. *What do you think about these hardships happening to the international community of the university? Did the VR experience increase your awareness of these hardships?*

2. *Could you please describe your initial reactions and thoughts to the stories told by the persons in the VR experience?*

3. *What would your reaction be if something similar happens in real life? (If an international person talks with you "in real life" about hardship experiences similar to the ones featured in the experiment.)*

Section IV: Benefits, Technology, and Going Forward: The last section of the interview asked about participants' considerations concerning the benefits of the VR application and similar systems and technology.

1. *Did you find this experience to be helpful to you or others in learning about the international community's hardships?*

2. *Who do you think such experiments could be most beneficial for, when developed further, and why?*

3. *How could technology be used to communicate difficult issues to a broader audience?*

Two colleagues (supervisors of the thesis) edited and validated the questions and the structure of the interview. Furthremore, since we planned to recruit mainly Finnish native participants, one native speaker colleague translated the interview template to Finnish (see 9). Then, another Finnish native speaker colleague validated the Finnish template of the interview.

5. EXPERIMENT DATA ANALYSIS

In this chapter, we present the result of the experiment and analyze them. In the first section, we explain the participants' demographics. Then, we describe and explore our collected data through QCAE in the second section. After that, we elaborate on participants' responses to the three questions related to the hardships via pre-experiment and post-experiment questionnaires. Finally, we present and explore our qualitative data analysis of participants' answers during the post-experiment semi-structured interview.

5.1. Participants' Demographics

During the VR experiment's performance for almost one month (from 19th April 2022 to 13th May 2022), 20 participants registered for the study through our research unit's own participant recruitment service, and 2 participants did not show up. Therefore, in total, we have 18 participants (11 Females, 6 Males, and 1 Non-binary) as follows: 11 participants are Finnish natives, 6 participants are not Finnish, and 1 participant selected half Finnish (from mother or father). All of them completed the experiment successfully.

The participants' age range is from 19 to 35 years old, that half of them are 20 to 22 years old. Our participants' mean and SD for their ages are 23.27 and 3.72, respectively. While students, staff, and graduates from the University of Oulu could register for the study, 66.7% of our participants are BSc students, and 33.3% are MSc students.

5.2. The QCAE Results

This section presents our results from participants' responses to QCAE in the pre-experiment questionnaire. As explained earlier, we asked our participants to fill out QCAE as the last part of the questionnaire before the experiment to allow us to measure the participants' empathy with it.

As shown in Table 2, all required metrics introduced in the QCAE article to measure human empathy is calculated for each participant based on their responses to this questionnaire. We followed the guideline presented in the QCAE article to calculate all empathy scores. To this end, first, we figured Perspective Taking score by summation of the participant's responses to these questions of QCAE: 15, 16, 19, 20, 21, 22, 24, 25, 26, 27. This score is indicated for each participant in the *Pers. Taking* column in Table 2. The mean and SD for participants' scores in Perspective Taking are 25.94 and 6.83, respectively.

Likewise, the Online Simulation score for each participant is calculated by summation of their responses to the following items of QCAE: 1 (reverse), 3, 4, 5, 6, 18, 28, 30, 31. This score is also presented in the *On. Sim.* column in Table 2. The mean and SD for participants' scores in Online Simulation are 26.61 and 3.56, respectively. Conclusively, participants' Cognitive Empathy scores are calculated by

Table 2. Participants' scores based on QCAE metrics and total empathy score.

	Cognitive Empathy			**Affective Empathy**				**Total**
Participant	Pers. Taking	On. Sim.	**SUM**	Emo. Con.	Prox. Resp.	Peri. Resp.	**SUM**	**Empathy Score**
P01	33	31	**64**	14	13	15	**42**	**106**
P03	24	32	**56**	15	15	14	**44**	**100**
P05	21	28	**49**	12	10	12	**34**	**83**
P06	27	25	**52**	16	14	13	**43**	**95**
P07	30	26	**56**	8	11	11	**30**	**86**
P08	25	22	**47**	11	10	10	**31**	**78**
P09	23	28	**51**	14	13	12	**39**	**90**
P10	35	29	**64**	11	14	14	**39**	**103**
P11	28	24	**52**	10	11	12	**33**	**85**
P12	12	25	**37**	12	12	13	**37**	**74**
P13	21	22	**43**	10	10	9	**29**	**72**
P14	35	30	**65**	14	14	13	**41**	**106**
P15	30	19	**49**	6	10	15	**31**	**80**
P16	12	26	**38**	10	10	8	**28**	**66**
P17	25	25	**50**	10	9	11	**30**	**80**
P18	33	30	**63**	15	13	11	**39**	**102**
P19	31	31	**62**	14	12	9	**35**	**97**
P20	22	26	**48**	14	10	9	**33**	**81**

summation of Perspective Taking and Online Simulation scores. The mean and SD for participants in the Cognitive Empathy score are 52.55 and 8.64, respectively.

To calculate participants' Affective Empathy scores, we calculated the summation of their scores for Emotion Contagion, Proximal Responsivity, and Peripheral Responsivity. These scores for each participant are shown as *Emo. Con.*, *Prox. Resp.*, and *Peri. Resp.* in Table 2, respectively. The Emotion Contagion score is calculated by summation of participants' responses to the following items of QCAE: 8, 9, 13, 14. The mean and SD for participants in the Emotion Contagion score are 12 and 2.70, respectively.

Furthermore, the Proximal Responsivity score is figured by summating participants' responses to 7, 10, 12, and 23 items. The mean and SD for participants' scores in Proximal Responsivity are 11.72 and 1.84, respectively. The Peripheral Responsivity is calculated by summation of participants' responses to 2 (reverse), 11, 17 (reverse), and 29 (reverse) items of QCAE. And the mean and SD for participants' scores in Peripheral Responsivity are 11.72 and 2.13, respectively. Also, the mean and SD for participants in the Affective Empathy score are 35.44 and 5.17, respectively.

Finally, each participant's total empathy score is calculated by summating the participant's scores in Cognitive Empathy and Affective Empathy. And, the mean and SD for participants' scores in total empathy are 88 and 12.36, respectively.

5.3. Questionnaire Results

As explained earlier, we asked our participants three questions before and after the VR experiment regarding the hardships. In this section, we present and compare the results of these questions one by one to investigate the experiment's effect on participants in those contexts.

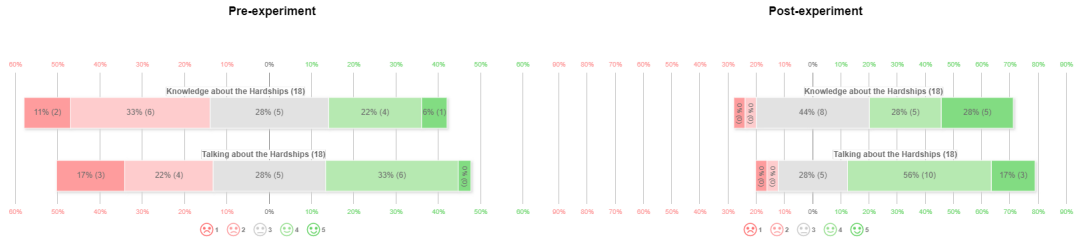

Figure 25. Participants' ratings for their knowledge and interest to talk about the hardships in pre-experiment and post-experiment questionnaires.

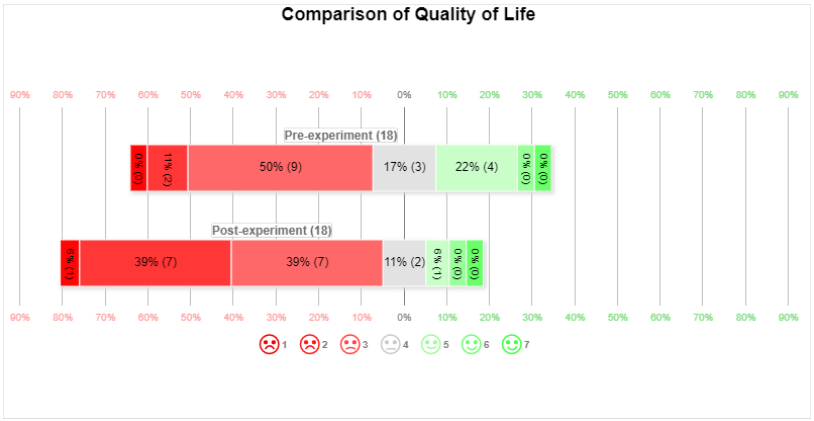

Figure 26. Participants' ratings for comparison of the international community's quality of life with theirs in pre-experiment and post-experiment questionnaires.

First, as indicated in Fig 25, generally, the VR experiment increased participants' knowledge about hardships that the international community of the University of Oulu faces. The figure shows that 72.22% of participants claimed they knew the average or less about the hardships before the VR experiment.

While 44.44% of participants declared that their knowledge about these hardships is less than the average in the pre-experiment questionnaire, 55.55% of them claimed that their understanding is more than the average in the post-experiment questionnaire. Also, after the experiment, all participants stated that their knowledge is now the same or more than the average.

As illustrated in Fig 25, our participants' tendency to talk about the international community's hardships increased. Based on our results from the pre-experiment questionnaire, the majority of the participants, which is 66.66% of all the participants, claimed that they talk about these hardships the same or less than the average.

Nevertheless, based on the post-experiment questionnaire, all of the VR experiment's participants declared that they would like to talk about these hardships with others now the same or more than the average. Also, we should mention that 72.22% of participants rated this question more than average after the experiment.

In the last question of the three hardships-related questions, before and after the VR experiment, participants rated their quality of life compared to the international community of the University of Oulu, as depicted in Fig 26. In the pre-experiment questionnaire, the majority of the participants, 61.11% of them, claimed that the international community's quality of life is worse than participants' quality of life.

Table 3. Participants' ratings and differences in the hardships-related questions.

	Knowledge about the Hardships			**Talking about the Hardships**			**Comparison of QoL**		
Participant	Pre-EXP	Post-EXP	**Diff**	Pre-EXP	Post-EXP	**Diff**	Pre-EXP	Post-EXP	**Diff**
P01	2	4	**+2**	2	5	**+3**	3	3	**0**
P03	1	3	**+2**	1	3	**+2**	3	2	**-1**
P05	1	3	**+2**	1	4	**+3**	3	3	**0**
P06	4	5	**+1**	3	4	**+1**	4	2	**-2**
P07	4	5	**+1**	4	4	**0**	4	4	**0**
P08	2	4	**+2**	2	3	**+1**	3	3	**0**
P09	2	3	**+1**	3	4	**+1**	3	2	**-1**
P10	3	5	**+2**	4	4	**0**	4	3	**-1**
P11	3	4	**+1**	3	4	**+1**	3	2	**-1**
P12	2	3	**+1**	1	3	**+2**	2	2	**0**
P13	2	3	**+1**	2	3	**+1**	3	2	**-1**
P14	3	3	**0**	3	4	**+1**	3	3	**0**
P15	3	3	**0**	2	4	**+2**	5	3	**-2**
P16	5	3	**-2**	4	3	**-1**	5	5	**0**
P17	4	5	**+1**	4	5	**+1**	3	1	**-2**
P18	2	4	**+2**	3	5	**+2**	2	2	**0**
P19	4	5	**+1**	4	4	**0**	5	3	**-2**
P20	3	4	**+1**	4	4	**0**	5	4	**-1**

Half of the participants answered this question by rating as 3, the next lesser score after the average (4 or equal in quality of life).

Furthermore, 7 participants claimed that the international community's quality of life is the same or better than theirs before the experiment. However, after the VR experiment, this number decreased to 3 participants. Also, 83.33% of all participants rated that the international community's quality of life is worse than theirs. And only one participant, after the VR experiment, stated that the international community's quality of life is better than the participant's quality of life.

As shown in Table 3, we present the results of the hardships-related questions in the pre-experiment and post-experiment questionnaires in more detail for each participant. In this table, all participants' responses to these three questions are indicated. The *Diff* columns present the differences in each participant's responses to these questions before and after the VR experiment to investigate how the experiment affected participants' understandings and tendency to talk about the hardships.

Likewise, we show how their thoughts regarding their quality of life compared to the international community are changed. As presented in Table 3, 83.33% of participants stated that their knowledge about the hardships is increased. Additionally, two participants claimed the VR experiment did not enhance their knowledge in this regard, and one participant mentioned that their knowledge is decreased.

Furthermore, 72.22% of our participants' tendency to talk about the hardships happening to the international community is increased, while four participants' responses are the same. And one participant is less willing to speak regarding these hardships with others after the experiment.

Finally, 55.55% of the participants rated a lower score for the international community's quality of life after the experiment compared to their responses in the pre-experiment questionnaire. Also, the rest of the participants did not change their rating in this regard.

Table 4. Mean and Standard Deviation for participants' ratings and differences in the hardship-related questions.

		Mean	**Standard Deviation**
Knowledge about the Hardships	Pre-experiment	2.77	1.11
	Post-experiment	3.83	0.85
	Difference	**1.05**	**0.99**
Talking about the Hardships	Pre-experiment	2.77	1.11
	Post-experiment	3.88	0.67
	Difference	**1.11**	**1.07**
Comparison of Quality of Life	Pre-experiment	3.5	0.98
	Post-experiment	2.72	0.95
	Difference	**-0.77**	**0.8**

In Table 4, we present the mean and SD for participants' responses to the three questions regarding the hardships in pre-experiment and post-experiment questionnaires. We show mean and SD for differences in participants' answers before and after the VR experiment in this table to investigate how the experiment affected their thoughts about the hardships.

Based on participants' responses, the mean of participants' ratings for their knowledge about the hardships increased by 1.05 from 2.77 to 3.83 (out of 5). Likewise, participants' interest in discussing the difficulties increased by 1.11 from 2.77 to 3.88 (out of 5). After the experiment, participants' ratings for comparing their quality of life with the international community decreased by 0.77 from 3.5 to 2.72 (out of 5).

Furthermore, we performed *Paired T-Test* on participants' responses to each of the three questions in pre-experiment and post-experiment questionnaires to statistically compare the changes in participants' thoughts for each subject in the questions. Paired T-Test is a statistical approach to comparing two populations' means where two samples could be paired based on the observations [121]. In our experiment, our participants for both questionnaires are the same.

For the first question, participants' knowledge about the hardships, $p - value$ is 0.00032, which is less than 0.05 (5%). Similarly, $p - value$ for the second question, participants' interest in talking about the hardships, and the third question, comparing the quality of life, are 0.00041 and 0.00077, respectively. These values are also less than 0.05.

Therefore, the means in these questions are not the same in pre-experiment and post-experiment questionnaires' responses. The calculated $p - values$ during Paired T-Test suggest that the VR experiment, on average, changed the participants' thoughts regarding these topics.

5.4. Interviews and Qualitative Data Analysis

This section presents deductive thematic data analysis [122] of the participants' responses during the semi-structured interview we had after the VR experiment. To this end, we followed the guidelines introduced by Caulfield [116]. We had an interview

with each participant in English or Finnish based on the participant's preference. Therefore, we analyzed 18 interview responses here in the four following sections.

5.4.1. The VR Experience and Experiment

Impression

In terms of the VR experience's impression, we mainly received positive responses from the participants during the post-experiment interviews. Several participants mentioned that the VR experience was impressive, surprising and interesting to them, and it made them think (re-think) about the hardships happening to the international community. For instance, P13 said: *"After the VR experience, I thought about the stories for a moment and just let my head process what I experienced."* and also P12 stated: *"I was surprised that people get treated based on their nationality."*

Also, several participants noted that the VR environment of the University increased the impression of the VR experience since the environment was familiar to them and they could recognize where they were, as P07 said *"felt by real"*. However, it is worth mentioning that P16 was the only participant who stated that the VR experience was not impressive because of using controllers for movements. P16 also said that the player was half size of NPCs. However, it was because this participant performed the experiment sitting.

Authenticity

In terms of the authenticity of the VR experience, we received responses with different points of view. Several participants claimed that the VR experience was authentic and realistic due to reasons such as hearing a 3D background crowd sound and recognizing the virtual university environment. For instance, P14 stated that: *"The location was so recognizable and the murmur of the crowd in the background made me feel like there were others there too. For a moment, I actually did feel like I was there."*

Nevertheless, some participants mentioned that there were not many details in the virtual environment or that the graphical quality of the experience was not very realistic. Also, few participants noted that how they had a conversation with NPCs, such as reading the stories as texts and the conversation flow, reduced the believability of the experience. In this regard, P11 said that: *"Not in the way that I would just go up and talk to a random person. People would probably not tell that directly or openly."*

Effectiveness

We asked our participants to reflect on their opinions on whether the VR experiment did what it was designed to do or not. Many participants claimed that the VR experiment did its job and helped them to went through the experience. P15 noted in this regard: *"I did think that there was an actual person there telling their story, that the story came from that person."*

Likewise, the VR experiment increased many participants' interest in the topic of the study. P18 stated during the interview: *"I felt like I would like to hear more about their experiences, and it was touching."* Three participants also mentioned that since the

stories were indicated to them as text, they could not realize the necessity of employing VR or compare the experiment with when they read the stories in an article.

Revision and Enhancement

We asked our participants' opinions on enhancing the VR experience in this interview section. Three participants said that we should employ voice-over for avatars to allow participants to listen to stories rather than read them. Several participants suggested enhancing the rotation system in the experiment since it caused them to feel dizziness. P10 noted that we need to improve the stories to make them more relatable to participants as said *"More versatility in the story elements of the system."*

Furthermore, several participants asked to improve the design of the VR experiment by adding more details to the environment, such as adding *L1* on the wall of the L1 lecture room. Two participants mentioned that the dialogue box should be changed with subtitles as an approach to reading the stories, or we move the dialogues to below the avatars. Also, as P17 stated: *"Maybe there could be more body language"*, we should improve the animation system by adding more animations to avatars.

5.4.2. Reflection on the Stories

Memorability

In terms of memorability of the stories, we asked our participants which stories and why they remembered most clearly. Several participants mentioned the stories that they experienced similar hardships, such as financial difficulties and finding a paid internship position. Also, some participants related themselves to some stories since they had been there when a similar situation happened to others. In this regard, P08 noted: *"Many people mention how people change to Finnish. I could imagine myself being guilty of that."*

Furthermore, some participants remember some stories more clearly because they knew another person who experienced that hardship. P20 brought an example in this regard as *"there was the one story about the bar experiencing harassment because I know a Brazilian person who has an afro who has experienced harassment in bars."*

Other participants mentioned several stories since they found those stories harsh and shocking, such as our first story, about a german person called Nazi. Also, some participants remembered the stories that they saw first and last, as they claimed. It is worth mentioning that mainly our Finnish participants mentioned the stories related to the language barrier as memorable stories.

Informativeness

Our participants elaborated on whether the stories included new information for them. Several participants stated that the stories contained many new topics and increased their knowledge. For instance, P18 noted in this regard: *"I got a feeling that international students have things worse than you might think. When you see them in a big group at the university, you might not necessarily think that they have issues with being lonely or having money."*

Besides, some participants expressed that they knew about some topics beforehand. However, the VR experiment told them new aspects of hardships that they had never experienced or knew about them, such as waiting for a long time for a resident permit. Two participants mentioned that the experiment was not informative to them since they already knew about the topics of the stories and the happening of these hardships. P17 said about this point of view as follows: *"Not really, when in primary school there were a lot of discussions about this. Half of the students didn't speak Finnish natively, and they told similar stories."*

Realisticness and Plausibility

We asked our participants to express their thoughts regarding the realisticness and believability of stories. Most of the participants mentioned that the stories were realistic and believable for several reasons, such as having familiar and varied topics and having good details in the stories. P01 noted this matter as *"Felt like chatting online"* during the interview and P11 stated: *"They sounded like realistic events, things that actually happen to some people."*

However, three participants, such P03, mentioned that some of the stories were hard to believe since they had no similar experiences. This participant stated this opinion as follows: *"However, if you haven't faced these kinds of things, (it) is more difficult to believe it has happened before."*

5.4.3. Influence on Empathy

Empathic Awareness

After the VR experiment, our participants elaborated on their empathic awareness and how the experiment affected them. Most participants mentioned directly that the VR experience increased their understanding of the hardships and the study topic. P01 noted during the interview: *"I've always known that there are some difficulties, but I have not thought about the scale of the effect on one's daily life."*

Furthermore, increasing the empathic awareness regarding the international community's hardships allowed some participants to review and express their opinions in this regard. For instance, P11 stated the following view: *"Maybe I'm living in some form of bubble where the people I know are more open. I suppose it's easy for me to forget that not everyone thinks of minorities in the way I do."*

As mentioned earlier, some participants had an idea about these hardships, but this study reminded them of these issues. In this regard, P17 said: *"The VR experience increased awareness and brought back the discussions I had many years ago. I haven't got a daily reminder of them. It reminded me of the issues people have."* Many participants expanded their responses on this topic and discussed their opinions on avoiding these hardships. We present this topic in the next section.

Empathic Reaction

We asked our participants about their empathic reactions during the interview, analogous to what P14 brought up: *"Could we on some level react better to these*

issues? For example, if you were in a situation where these things happen, you would react immediately and not just let them happen." Many participants expressed that their empathic reactions would depend on the situation, the context and topic of the hardship, and their relation with the person who experienced it.

Several participants started their responses with phrases such as *"I don't know"* or *"It's hard to answer"*. In contrast, some participants mentioned that they would attempt to help, be a good listener, ask more about what happened, and be empathic such as P10 mentioned: *"But I would not judge either the person being the target of the hardship or the person who is the 'cause.'"*

Some participants also noted that these reactions would be general and are not limited to when someone tells them about the hardship experienced. For instance, P13 stated that: *"Whenever I interact with exchange students or international folk, I try to take them into consideration and create a sense that they belong in the group."*

5.4.4. Benefits, Technology, and Going Forward

Stakeholders and Beneficiary Groups

Our participants explained different types and groups of people who would be benefited from this VR application if we develop it further. Some participants expressed that generally, anyone could be in the beneficiary group, as P10 stated in this regard: *"Limitless scope. You can raise awareness in anyone. Just being exposed to these hardships will improve people's understanding and awareness."*

Nonetheless, several participants claimed that this system could be more beneficial for natives or, in more detail, for people who have not been in touch with foreigners. P01 noted this opinion as to the following statement: *" People who haven't been in contact with different cultures would likely be the ones to benefit most."* In contrast, some participants mentioned that this system could help international people become familiar with the situation and reflect their issues to others.

Furthermore, several participants discussed this topic with a distinct view of point. Some mentioned that official authorities and responsible organizations could benefit greatly from this system. For instance, responsible persons at the university and immigration authorities could help international students to get their resident permits if they become aware.

Likewise, several participants expressed their opinions about how this system could be helpful for younger people or vice versa. They claimed younger people benefit more from this system since they would be more interested in game-like experiences and could be employed in societal studies at schools. In this regard, P14 noted: *"Even if the kids don't fully understand the matters or can relate to everything, it would still be instructive."*

VR Usefulness

During the interviews, participants discussed the advantages and disadvantages of employing VR technologies in this study. They elaborated on their opinions by sharing their experience during our experiment. Most participants agreed that VR was a

promising approach for this study since it has more impact than other approaches with similar attitudes, such as reading from a paper. P09 also stated: *"It was far better than reading some texts from a screen."*

Similarly, P19 noted that *"You can see the environment, and you can go by yourself. It is more interesting than on a paper or a website."* Analogous to that statement, many participants mentioned that being in the interactive virtual environment helped them connect better with the stories and avatars.

Technology Utilization

We asked our participants to express their ideas regarding approaches to using technology to communicate our topic to a broader audience. Several participants mentioned that VR is a promising technology for discussing these problematic issues. In this regard, P12 noted: *"I think the virtual space makes the experience more memorable."*

Nevertheless, many participants claimed that VR is not yet generally accessible to everyone, making it difficult to reach a vast audience. Therefore, some participants suggested several ways, such as video games, movies, and documentaries, on publicly available platforms. Some participants also mentioned new enhancements to achieve better to a large audience. For instance, P16 suggested translating the stories to Finnish to ensure everyone could understand them. Also, P18 brought an idea to share the stories in public spaces such as bus stations.

6. DISCUSSION

In this study, we collected several hardships that the University of Oulu's international community faces during their lives and studies in Oulu through a survey. It is shown in much research that VR is a promising approach compared to other technologies to put people in others' shoes to showcase their hardship experiences [29, 110, 27], particularly for empathic and challenging issues such as social problems [26, 111]. Therefore, we employed collected stories to develop a VR experiment to showcase the hardships to mainly local participants to measure their situated empathy.

The QCAE is a recent quantitative technique to measure people's cognitive and affective empathy [32]. Also, semi-structured interviews allow participants to reflect on a topic in-depth [123, 124]. We employed quantitive and qualitative methods such as the QCAE, pre-experiment and post-experiment questionnaires, and semi-structured interviews to measure the situated empathy in participants.

In this chapter, we first revisit the thesis objectives and research questions and elaborate more on our results compared to related efforts. Then, we explore the thesis stakeholders and significance to our organization and society. Then, we reflect on several VR-related issues in design and implementation based on the participants' interviews, research literature, and the author of the thesis insight. We also explain the key limitations of the thesis and conclude this chapter with an introduction to our future work.

6.1. Revisiting Thesis Objectives and Research Questions

Objective I: Collect information on the hardships that the international community faces at the University of Oulu.

Collecting hardship experiences such as financial difficulties from participants is a critical and susceptible process in research [125, 126]. It becomes more complicated when participants require to describe experiences that might affect their lives, such as racism and social harassment, particularly due to ethical considerations [127, 128]. Also, in that case, it is critical to provide validity and trust for participants to allow them to express their experiences and feelings attached without being offended or induced [129, 130].

To achieve the first objective of the thesis, we created a website, namely *weareoulu.com*. Then, we designed a survey to anonymously collect participants' demographic information and hardships experienced in Finland as a part of the international community of the University of Oulu. On both the project's website and the story collection survey, we put all detailed information regarding the project's owners, such as responsible researchers' contacts, to allow our participants to trust the project.

Therefore, we collected hardship experiences on distinct topics from 40 participants from the University of Oulu international community with 20 different nationalities through the story collection survey.

Objective II: Develop a VR application to investigate communicating a subset of the collected hardships to the local community.

Many researchers have indicated that VR is practical in enhancing human empathy [25]. VR has proved that it is an impactful technology to teach empathy, especially when communicating difficult issues with an audience [23, 22, 105]. Many efforts compared VR with other media technologies and named VR the ultimate empathy tool [112, 113, 114].

In this thesis, we employed VR as the leading technology to showcase the hardship experiences we collected in the study's first phase. To this end, we developed our VR application with several NPCs to describe the hardship experiences as stories to our participants. We selected the stories from the collected hardship experiences with a wide range of topics to cover the main mentioned topics.

Researchers discussed that it must be considered in making the audience empathic or sympathetic [23]. In similar experiments, researchers showed that participants would be sympathetic and might even be offended if they were the person who was experiencing the situated empathy [23]. Being sympathetic might cause effective feelings such as anger which is not the purpose of the study [131].

In our VR application, we designed a pre-made conversation with NPCs to allow participants to see and understand the hardships by conversing with the person who experienced the difficulty. In this case, analogous to some prior works that other researchers have done, the VR application makes participants empathic since they read the stories and put themselves in the person's shoes who experienced the hardship [110, 111].

RQ I: What kind of hardships are experienced by the international community of the University of Oulu?

After the data collection phase, we conducted thematic data analysis on the collected hardships to investigate the topics mentioned in the responses [115, 116]. Topics of the hardships are as follows: Social Problems, Language Barriers, Bureaucracy, Racism, Job Seeking, Financial, Weather, Cultural Barriers, Immigration, and Daily Interactions issues.

Collected stories revealed that many participants in the study's first phase are suffering from these difficulties. The topics mentioned in the survey's responses in the context of stories by participants. Many participants also described that these hardships affected their lives and mental health. For instance, one participant said she visited a therapist due to depression and stress. Depression, anxiety, and post-traumatic stress are exposed by researchers as possible outcomes of immigration's hardships [8].

Several participants noted in their responses that their experienced hardships were due to several uncontrollable reasons, such as cultural differences. It is debated that being adapted to an entirely new place with a different culture, language, and society's behavior might lead to mental problems and affect employment, social status, and integration [9].

RQ II: What effects does communicating the hardships of the international community have on the local participants?

We investigated the result of pre-experiment and post-experiment questionnaires. Comparing and analyzing questionnaires' results indicated that participants' knowledge and understanding of the hardships happening to the university's international community and their lives increased on average after the VR experiment. Also, it showed that participants would like to talk more about these issues with others.

It has been shown that qualitative methods in measuring situated empathy are impactful since it allows researchers to understand participants' insight in-depth [123, 124]. Interviews would let researchers ask many open-ended questions that might be left blank in questionnaires [124]. Also, it is a common issue that some participants might have lacked attention during the study [132]. However, conducting interview help, researchers handle this issue [124].

Therefore, in addition to the questionnaires, we analyzed the qualitative data collected through a semi-structured interview after the experiment. Participants reflected on the VR experiment, stories, and their empathy during the interview and represented enhancing empathy with a positive attitude [27].

It is discussed that the language barrier is one of the most influential negative factors in conducting interviews [133]. Since we had mainly Finnish native participants during the experiment, we solved this challenge by having a colleague who was a native Finnish speaker during the experiment sessions. The possibility of conducting the interviews in Finnish allowed many participants to smoothly speak about their thoughts and feelings in the preferred language since some Finnish participants still chose to discuss in English.

RQ III: How suitable is VR as technology in communicating hardship experiences of the international community to the local participants?

First, as evident in the interview results, many participants expressed that the stories were believable and plausible for them. They also noted that the experiment was practical in understanding the international community's hardships due to several reasons, such as being in the environment and interacting with NPCs. VR has indicated a more substantial impact on enhancing empathy compared to other technologies to showcase content regarding others' hardship experiences as it can simulate an environment for experiencing situated empathy [26, 110, 111, 27].

It has been debated that VR enhances human empathy more effectively than desktop monitors or videos [26, 111]. Likewise, Several participants mentioned that reading those stories in the virtual university environment was better than reading text on desktop monitors and articles.

Secondly, during the interviews, our participants reflected on what technologies could be employed to communicate these issues with the audience. Many participants suggested VR as the most impactful approach to allow the audience *to be there* while experiencing the situated empathy analogous to researchers who have called VR the ultimate empathy machine [28, 112, 113, 114].

6.2. Exploring Stakeholders and the Significance of the Thesis

Overall, this thesis increased our local participants' knowledge and tendency to discuss these hardships. Presenting the hardships that several members of the international community of the University of Oulu experienced through a VR application enhanced empathy with a positive attitude in the audience. Our local and international participants expressed that the VR application helped increase their awareness during the experiment. The enhancement in both local and international audience empathy help to understand better the other side. For instance, the people would help the international community integrate smoothly. On the other hand, the international people would know how to react better in hardship situations, such as understanding the cultural difference.

Likewise, this application can increase local people's awareness of the international community's hardships, particularly helping those with lesser contact with the international community. Also, as some participants suggested, it can be used in schools and the University of Oulu to let young people put themselves in the international community's shoes to increase their situated empathy and knowledge regarding these hardships. The University of Oulu and other related authorities such as immigration offices could be aware of these hardships through this application. Then, they could help the international community with these hardships.

Also, based on the information we collected in the first step of the study, our participants, as part of the University of Oulu's international community, experienced hardships during their studies and lives in Oulu. However, mainly they rated their quality of life in Finland compared to other countries as more than the average. Therefore, the authorities' positive reaction to these hardships would enhance the international quality of life. For instance, the immigration authority can accelerate the issuing of resident permit procedures with the help of the university. Also, the university authorities can hold more programs to help international students integrate with Finnish students.

In the bigger picture, these enhancements would allow Finland to attract and provide more labor and experts for the industry, economy, public services, etc. This conclusion also improves domestics' quality of life.

6.3. Reflection on Design and Implementation Issues

Developing a VR application is different from other platforms' applications shown on a desktop or projection display system. In VR, players are in the virtual environment to experience what is designed for them. Several concepts such as presence and immersion are the essential aspects of VR development [90].

Furthermore, since VR stimulus players' brains to believe what they experience, it raises a vital discussion, namely Virtual Reality Induced Symptoms and Effects (VRISE) [134, 135]. Oculus published a comprehensive guide for developers to prevent or reduce these symptoms and effects during VR experiences [136]. Also, there are always discussions among researchers and developers communities to cover design and implementation issues in VR as much as possible.

Here in this section, we discuss several mentionable design issues that we have faced and considered during the design and implementation of the project. Also, we debate several design issues that our participants addressed during the post-experiment interviews.

Footstep Sound

One critical but unknown issue we upfronted during the implementation was the footstep sound. It is evident during the game development that the main character or the player character must have a footstep sound; otherwise, it seems that the avatar is moving above the ground, similar to a ghost. It is also straightforward to implement the footstep sound. The audio should just be played whenever the character moves in any direction. In many games, developers also change the footstep sound's speed based on the character's speed or employ different audio sources.

However, this design issue is different when it comes to virtual reality and complicated to have a general conclusion [137]. In VR, if players do not move during their VR experience, they would be aware that they are stable in the real world during the experience. So, the sound would not increase the sense of presence and might only be annoying after a while. Also, if players would not see themselves during the experience, hearing footstep sounds in VR would seem to the players that someone is chasing them.

Last but not least, the immersion of the VR experience is important. But, this design issue could reduce the immersion of the experience based on the reasons explored above. Since during our VR experience, players did not see their virtual bodies and did not move their actual bodies, we should not employ the footstep sound.

Camera Coordination with Player's Movement

Camera coordination during players' movements is another design issue we should discuss here. First, we need to clarify what this design issue means and why we need to define and investigate it.

In many games with the first-person point of camera view, the camera moves a little coordinately with the player's movement to simulate the movement of the character's head during walking or running. It increases the immersion of the experience. However, it should be precisely considered when it comes to VR [138]. The extra camera movement would be annoying for players in VR. It not only can reduce the immersion of the experience but also might cause symptoms such as visual discomfort and dizziness in players. Therefore, we did not employ this movement in the project.

Subtitle and Dialogue Box

In Section 5.4.1, we presented several enhancements that our participants suggested during the interviews. Among these suggestions, some participants criticized our approach to indicating the stories' texts to participants in the VR experiment. Some participants suggested employing the common practice to display subtitles, showing the texts on the bottom of the field of view (FOV) analogous to desktop monitors rather than the current system, which is the dialogue box.

A dialogue box is an interactive panel, one way to display texts as subtitles in a VR application [139]. As explained in Chapter 4, we implemented our interactive panel as an attached dialogue box which moves and rotates based on the player's location when it is initiated. In our approach, text and the dialogue box are rendered as World Space that the Canvas units are in meters, and participants could see as they saw boards in the real world.

They could also move freely during the conversation without being chased by texts in front of the camera. This approach would provide freedom for users to how they would like to see and read texts compared to traditional subtitles. In the traditional approach to displaying subtitles, the text would be rendered in front of the camera called *Screen Space* render mode. As investigated in VR developers' communities, there is a rule of thumb to employ World Space render mode for Canvases instead of Screen Space while creating a VR environment [86].

Voice over Characters

During the interviews after the VR experiment, some participants expressed that we should employ voices over NPCs in the VR application to describe the stories. They mentioned several reasons for their suggestions, such as increasing the experience's immersion and increasing focus during the experiment. Many researchers have investigated this debation [140]. It is proven that audio in a game-like experience improves physiological responses and immersion [141, 142, 143, 144, 145].

In the study design phase, we also thought about approaches to employing voice-over NPCs and also a background music. However, after our investigation, we decided to decline this idea since it would affect the results as discussed. In this study, we would like to measure human empathy regarding the hardships and stories we collected. Also, there is a discussion on how speakers' voices, tones, genders, etc., affect empathy in humans [146, 147]. Therefore, employing voices for avatars would lead us through a new study with many new factors that could affect our participants' empathy.

6.4. Limitations of the Thesis

In this section, we acknowledge several limitations of the thesis.

First of all, one of the critical limitations of the thesis is the number of participants in both the story collection and the VR experiment steps. We attempted to connect with the university's international community in different ways, such as inviting them through email and events. In the end, we collected stories from 40 international participants during the first step of the study.

Although initially, we expected to receive more responses, due to the COVID pandemic, we could not find a chance to promote the study more in person. It becomes a limitation in the thesis since it has shown that in-person engagement is more than online engagement [148]. The difference between in-person and online engagements would be noticeable when interviewing participants with these approaches [149].

Furthermore, since most classes were online during the pandemic, there were not many students and staff at the university to reach the survey through the posters we

installed on the campus. We had several email lists to promote the study via sending emails, but many of them required administration approvals.

We employed a human subject experiment laboratory during the VR experiment, which was shared with several researchers and other ongoing studies. Therefore, we could hold the study three days per week. Also, due to university guidelines for maintaining in-person experiments during the pandemic, we had to limit the number of participants in each experiment day and consider a break time to disinfect equipment and the place before the next participant.

Furthermore, since we agreed to have a semi-structured interview after the VR experiment for our participants, who were primarily Finnish natives, we were required to have a Finnish speaker colleague during each session. It means that the author of the thesis and his Finnish colleagues were demanded to agree on available dates and times for experiment sessions before participants' registrations. Due to the arguments explored in this and the last paragraphs, we conducted the study experiment with 20 registered participants.

Although the sufficient sample size of a study depends on many factors, such as the context, it is critical when data saturation occurs in the study [150]. Also, when the discussion comes to a study with a qualitative data collection and analysis, such as conducting interviews with participants, many articles indicate a number between 5 to 50 participants [151]. Our study, since we had mainly Finnish native participants, stated a relatively homogeneous population that data saturation could occur with a sample size of 12 [152]. Our study ended up with 18 participants, which indicates an adequate number of participants. However, as discussed above, many reasons lowered this number.

As mentioned earlier in this chapter, one of the research questions we answered with this thesis was investigating the effects of communicating the hardships of the university's international community on local participants. In this regard, since we had 18 participants in the experiment, it is a key limitation of the study that the number of participants was relatively small. One critical issue with a small sample size is that it could lead the investigation to variability and uncoverage biases [153].

6.5. Future Work

We have several ideas and plans to improve the project in both technical and non-technical aspects as the future work of the study. First of all, to increase the immersion of the virtual environment, we would like to add interior furniture to the model analogous to the actual university environment. Likewise, we would like to add a lightmap to employ the lighting system of the Unity engine with lighting objects such as *Point Light*. To this end, we should do some performance optimization in the future. For instance, we would like to enhance our implementation to let the engine only render the visible part of the environment to the player.

Furthermore, we would like to repeat the study with another group of participants in a virtual environment other than the university environment to investigate the effect of being in the university environment compared to an environment such as a random building or cafe. As suggested by several participants during the study's experiment, we would like to add voice-over NPCs to tell the stories more naturalistic. Then,

we would measure and compare the situated empathy with new participants. Also, it could be a more advanced study to employ several Natural Language Processing (NLP) methods to allow participants to initiate the conversation with NPCs via their own sentences using a microphone.

As another step toward going forward with our study, we would like to enhance further and develop the VR application. After that, we build the project as a VR and Android application to increase its accessibility. Therefore, we would publish both applications locally and ask the people of Oulu to participate in our study by installing and playing the *We Are Oulu* application on their Android or HMD devices. Every participant would be asked to fill out pre-experiment and post-experiment questionnaires through the application.

Therefore, we would collect valuable data from our participants to answer two new research questions. First, we can investigate how the application increases the domestic community's awareness of these hardships. Secondly, since the participants would be able to join the study with smartphones, we can explore whether VR is an effective technology for our purpose compared to other technologies or approaches, such as smartphones.

7. CONCLUSION

In this thesis, we developed a VR experience to explore situated empathy regarding the hardship experiences that the international community of the University of Oulu faces during their studies and lives in Oulu. First, we developed a website and an online survey to collect the hardship experiences among students, staff, and any related person to the University of Oulu international community. This study phase involved collecting hardship stories and data from 40 participants. The results revealed that social problems, language barriers, issues with bureaucracy, and racism are mainly hardship experiences topics. Then, we developed a VR experience that let our participants read the stories about the hardship experiences through simulated conversations and interactions with avatars in the University of Oulu's virtual environment. We experimented with the VR application with 18 participants who were mainly Finnish natives and asked them to respond to pre- and post-experiment questionnaires and a follow-up semi-structured interview.

The results of the experiment questionnaires indicated that the average participants' responses to their knowledge and tendency to discuss the hardships increased by 1.05 and 1.11 on the 5-point scale, respectively. Likewise, the results showed that they rated the international community's quality of life worse after the experiment by decreasing the average of responses by 0.77 on the 7-point scale compared to themselves. Evaluation of the follow-up interview responses presented enhancement in participants' situated empathy and awareness about the hardships of the international community. It also indicated mainly positive considerations on the VR experience's believability, the stories' plausibility, and the impact of VR as a promising technology in fostering empathy.

8. REFERENCES

[1] Scheffler S. (2005) Choice, circumstance, and the value of equality. Politics, Philosophy & Economics 4, pp. 5–28.

[2] Parsons T. (1970) Equality and inequality in modern society, or social stratification revisited. Sociological Inquiry 40, pp. 13–72.

[3] Rosanvallon P. (2014) The society of equals: Restoring democratic equality in relations. Juncture 20, pp. 249–257.

[4] Trubek L.G. & Das M. (2003) Achieving equality: healthcare governance in transition. American Journal of Law & Medicine 29, pp. 395–421.

[5] Shannon G., Jansen M., Williams K., Cáceres C., Motta A., Odhiambo A., Eleveld A. & Mannell J. (2019) Gender equality in science, medicine, and global health: where are we at and why does it matter? The Lancet 393, pp. 560–569.

[6] Lowe L. (1996) Immigrant Acts: On Asian American Cultural Politics. Duke University Press. URL: https://doi.org/10.1515/9780822379010.

[7] Cade J.A. (2015) Enforcing immigration equity. Fordham L. Rev. 84, p. 661.

[8] Martinez O., Wu E., Sandfort T., Dodge B., Carballo-Dieguez A., Pinto R., Rhodes S., Moya E. & Chavez-Baray S. (2015) Evaluating the impact of immigration policies on health status among undocumented immigrants: a systematic review. Journal of immigrant and minority health 17, pp. 947–970.

[9] Kirmayer L.J., Narasiah L., Munoz M., Rashid M., Ryder A.G., Guzder J., Hassan G., Rousseau C. & Pottie K. (2011) Common mental health problems in immigrants and refugees: general approach in primary care. Cmaj 183, pp. E959–E967.

[10] News Y. (2021), Fm saarikko: Finland needs to accept more foreign workers. URL: https://yle.fi/news/3-12021081.

[11] Office P.M. (2020), Voluntary national review 2020 finland: Report on the implementation of the 2030 agenda for sustainable development. URL: https://julkaisut.valtioneuvosto.fi/handle/10024/162268.

[12] Hakkarainen O. (2020), Social security with inequalities and big footprint. URL: https://www.socialwatch.org/node/18507.

[13] Nalani A., Yoshikawa H. & Carter P.L. (2021) Social science–based pathways to reduce social inequality in youth outcomes and opportunities at scale. Socius 7, p. 23780231211020236.

[14] Dorling D. & Jones O.P. (2017) The equality effect: Improving life for everyone. New Internationalist Publications Limited Oxford.

[15] Sherman A., Trisi D., Stone C., Gonzales S. & Parrott S. (2019) Immigrants Contribute Greatly to US Economy, Despite Administration's ZPublic Chargey Rule Rationale. JSTOR.

[16] Gordon I.R., Travers T. & Whitehead C.M. (2007) The impact of recent immigration on the london economy .

[17] Clench-Aas J. & Holte A. (2018) Measures that increase social equality are effective in improving life satisfaction in times of economic crisis. BMC public health 18, pp. 1–11.

[18] Weinberg A.M. (1966) Will technology replace social engineering? Fifteenth Annual Alfred Korzybski Memorial Lecture (Harvard Club of New York: Institute of General Semantics) .

[19] Johnston S.F. (2018) The technological fix as social cure-all: Origins and implications. IEEE Technology and Society Magazine 37, pp. 47–54.

[20] Gelb S. & Krishnan A. (2018) Technology, migration and the 2030 agenda for sustainable development. London: Overseas Development Institute .

[21] Bujić M., Salminen M., Macey J. & Hamari J. (2020) "empathy machine": how virtual reality affects human rights attitudes. Internet Research .

[22] Steed A., Pan Y., Watson Z. & Slater M. (2018) "we wait"—the impact of character responsiveness and self embodiment on presence and interest in an immersive news experience. Frontiers in Robotics and AI 5, p. 112.

[23] Ramirez E.J. (2020) Can technology help us be more empathetic? racism, empathy and virtual reality. Markkula Center for Applied Ethics at Santa Clara University 15.

[24] Shin D. (2018) Empathy and embodied experience in virtual environment: To what extent can virtual reality stimulate empathy and embodied experience? Computers in human behavior 78, pp. 64–73.

[25] Paananen V., Kiarostami M.S., Lee L.H., Braud T. & Hosio S. (2022) From digital media to empathic reality: A systematic review of empathy research in extended reality environments. arXiv preprint arXiv:2203.01375 .

[26] Christofi M., Michael-Grigoriou D. & Kyrlitsias C. (2020) A virtual reality simulation of drug users' everyday life: the effect of supported sensorimotor contingencies on empathy. Frontiers in psychology 11, p. 1242.

[27] Herrera F., Bailenson J., Weisz E., Ogle E. & Zaki J. (2018) Building long-term empathy: A large-scale comparison of traditional and virtual reality perspective-taking. PloS one 13, p. e0204494.

[28] Hargrove A., Sommer J.M. & Jones J.J. (2020) Virtual reality and embodied experience induce similar levels of empathy change: Experimental evidence. Computers in Human Behavior Reports 2, p. 100038.

[29] Kiarostami M.S., Visuri A. & Hosio S. (2022) We are oulu: Exploring situated empathy through a communal virtual reality experience. In: 2022 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW), IEEE, pp. 966–967.

[30] English Dictionary C. (2018), Human empathy definition and meaning: Collins english dictionary 13th edition. URL: https://www.collinsdictionary.com/dictionary/english/human-empathy.

[31] English Dictionary M.W. (2022), Empathy definition & meaning. URL: https://www.merriam-webster.com/dictionary/empathy.

[32] Reniers R.L., Corcoran R., Drake R., Shryane N.M. & Völlm B.A. (2011) The qcae: A questionnaire of cognitive and affective empathy. Journal of personality assessment 93, pp. 84–95.

[33] Bennett J.A. (1995) " methodological notes on empathy": Further considerations. Advances in Nursing Science 18, pp. 36–50.

[34] Chlopan B.E., McCain M.L., Carbonell J.L. & Hagen R.L. (1985) Empathy: Review of available measures. Journal of personality and social psychology 48, p. 635.

[35] Jolliffe D. & Farrington D.P. (2004) Empathy and offending: A systematic review and meta-analysis. Aggression and violent behavior 9, pp. 441–476.

[36] Eisenberg N. et al. (2000) Emotion, regulation, and moral development. Annual review of psychology 51, pp. 665–697.

[37] Vreeke G.J. & Van der Mark I.L. (2003) Empathy, an integrative model. New Ideas in Psychology 21, pp. 177–207.

[38] Cohen D. & Strayer J. (1996) Empathy in conduct-disordered and comparison youth. Developmental psychology 32, p. 988.

[39] Hodges S. & Myers M. (2007) Encyclopedia of social psychology. Empathy , pp. 296–298.

[40] Riess H. (2017) The science of empathy. Journal of patient experience 4, pp. 74–77.

[41] Stueber K. (2019) Empathy. In: E.N. Zalta (ed.) The Stanford Encyclopedia of Philosophy, Metaphysics Research Lab, Stanford University, Fall 2019 ed.

[42] Van Dongen J.D. (2020) The empathic brain of psychopaths: From social science to neuroscience in empathy. Frontiers in Psychology 11, p. 695.

[43] Blair R. (2005) Responding to the emotions of others: Dissociating forms of empathy through the study of typical and psychiatric populations. Consciousness and Cognition 14, pp. 698–718. URL: https://www.sciencedirect.com/science/article/pii/S1053810005000851, the Brain and Its Self.

[44] Frith U. (2003) Autism: Explaining the enigma. Blackwell Publishing.

[45] Leslie A.M. (1987) Pretense and representation: The origins of" theory of mind.". Psychological review 94, p. 412.

[46] Premack D. & Woodruff G. (1978) Does the chimpanzee have a theory of mind? Behavioral and brain sciences 1, pp. 515–526.

[47] Jodi Clarke M. (2021), How empathy can improve your relationships. URL: https://www.verywellmind.com/cognitive-and-emotional-empathy.

[48] Bons D.M., Scheepers F.E., Rommelse N.N. & Buitelaar J.K. (2010) Motor, emotional and cognitive empathic abilities in children with autism and conduct disorder. In: Proceedings of the 7th International Conference on Methods and Techniques in Behavioral Research, pp. 1–5.

[49] Mahayana I.T., Banissy M., Chen C.Y., Walsh V., Juan C.H. & Muggleton N.G. (2014) Motor empathy is a consequence of misattribution of sensory information in observers. Frontiers in Human Neuroscience 8, p. 47.

[50] Hatfield E., Cacioppo J.T. & Rapson R.L. (1993) Emotional contagion. Current directions in psychological science 2, pp. 96–100.

[51] Bariso J. (2018), There are actually 3 types of empathy. here's how they differ–and how you can develop them all. URL: https://www.inc.com/justin-bariso/there-are-actually-3-types-of-empathy-heres-how-they-differ-and-how-you-can-develop-them-all.html.

[52] Mazza M., Pino M.C., Mariano M., Tempesta D., Ferrara M., De Berardis D., Masedu F. & Valenti M. (2014) Affective and cognitive empathy in adolescents with autism spectrum disorder. Frontiers in human neuroscience 8, p. 791.

[53] Decety J. & Jackson P.L. (2006) A social-neuroscience perspective on empathy. Current directions in psychological science 15, pp. 54–58.

[54] Gini G., Albiero P., Benelli B. & Altoe G. (2007) Does empathy predict adolescents' bullying and defending behavior? Aggressive Behavior: Official Journal of the International Society for Research on Aggression 33, pp. 467–476.

[55] Ze O., Thoma P. & Suchan B. (2014) Cognitive and affective empathy in younger and older individuals. Aging & mental health 18, pp. 929–935.

[56] Young S., Gudjonsson G.H., Terry R. & Bramham J. (2008) Victim empathy response assessment (vera): The validation of a new measure for forensic patients. The Journal of Forensic Psychiatry & Psychology 19, pp. 191–204.

[57] Friesem J. (2010), Empathy questionnaires table. URL: http://cultureofempathy.com/References/Test.htm#Empathy_Questionnaires_Table_-_Compiled_by_Jonathan_Friesem.

[58] Butters R.P. (2010) A meta-analysis of empathy training programs for client populations. The University of Utah.

[59] Stueber K. (2019), Measuring empathy. URL: https://plato.stanford.edu/entries/empathy/measuring.

[60] Zhou Q., Valiente C. & Eisenberg N. (2003) Empathy and its measurement. .

[61] Maibom H.L. (2017) The Routledge handbook of philosophy of empathy. Routledge New York.

[62] Konrath S., Meier B.P. & Bushman B.J. (2018) Development and validation of the single item trait empathy scale (sites). Journal of research in personality 73, pp. 111–122.

[63] Dymond R.F. (1949) A scale for the measurement of empathic ability. Journal of consulting psychology 13, p. 127.

[64] Block J. (1963) The q-sort method in personality assessment and psychiatric research. The Journal of Nervous and Mental Disease 136, pp. 604–605.

[65] Hogan R. (1969) Development of an empathy scale. Journal of consulting and clinical psychology 33, p. 307.

[66] Mehrabian A. & Epstein N. (1972) A measure of emotional empathy. Journal of personality .

[67] Davis M.H. et al. (1980) A multidimensional approach to individual differences in empathy .

[68] Bryant B.K. (1982) An index of empathy for children and adolescents. Child development , pp. 413–425.

[69] Mehrabian A. (1997) Relations among personality scales of aggression, violence, and empathy: Validational evidence bearing on the risk of eruptive violence scale. Aggressive Behavior: Official Journal of the International Society for Research on Aggression 23, pp. 433–445.

[70] Hojat M., Mangione S., Nasca T.J., Cohen M.J., Gonnella J.S., Erdmann J.B., Veloski J. & Magee M. (2001) The jefferson scale of physician empathy: development and preliminary psychometric data. Educational and psychological measurement 61, pp. 349–365.

[71] Baron-Cohen S. & Wheelwright S. (2004) The empathy quotient: an investigation of adults with asperger syndrome or high functioning autism, and normal sex differences. Journal of autism and developmental disorders 34, pp. 163–175.

[72] Spreng* R.N., McKinnon* M.C., Mar R.A. & Levine B. (2009) The toronto empathy questionnaire: Scale development and initial validation of a factor-analytic solution to multiple empathy measures. Journal of personality assessment 91, pp. 62–71.

[73] Gigante M.A. (1993) Virtual reality: definitions, history and applications. In: Virtual reality systems, Elsevier, pp. 3–14.

[74] Wikipedia G.o.A. (2022), Virtual reality. URL: https://en.wikipedia.org/wiki/Virtual_reality#History.

[75] Cipresso P., Giglioli I.A.C., Raya M.A. & Riva G. (2018) The past, present, and future of virtual and augmented reality research: a network and cluster analysis of the literature. Frontiers in psychology , p. 2086.

[76] Zheng J., Chan K. & Gibson I. (1998) Virtual reality. Ieee Potentials 17, pp. 20–23.

[77] Radianti J., Majchrzak T.A., Fromm J. & Wohlgenannt I. (2020) A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. Computers & Education 147, p. 103778.

[78] Wikipedia G.o.A. (2022), Head-mounted display. URL: https://en.wikipedia.org/wiki/Head-mounted_display.

[79] Kress B. & Starner T. (2013) A review of head-mounted displays (hmd) technologies and applications for consumer electronics. Photonic Applications for Aerospace, Commercial, and Harsh Environments IV 8720, pp. 62–74.

[80] Holzwarth V., Gisler J., Hirt C. & Kunz A. (2021) Comparing the accuracy and precision of steamvr tracking 2.0 and oculus quest 2 in a room scale setup. In: 2021 the 5th International Conference on Virtual and Augmented Reality Simulations, pp. 42–46.

[81] Wikipedia G.o.A. (2022), Game engine. URL: https://en.wikipedia.org/wiki/Game_engine.

[82] Lagos-Ortiz K. (2016) Technologies and Innovation, Second International Conference, CITI 2016, Guayaquil, Ecuador, November 23-25, 2016, Proceedings, Communications in Computer and Information Science 658.

[83] Haas J.K. (2014) A history of the unity game engine. Diss. WORCESTER POLYTECHNIC INSTITUTE 483, p. 484.

[84] Foxman M. (2019) United we stand: Platforms, tools and innovation with the unity game engine. Social Media+ Society 5, p. 2056305119880177.

[85] Brookes J., Warburton M., Alghadier M., Mon-Williams M. & Mushtaq F. (2020) Studying human behavior with virtual reality: The unity experiment framework. Behavior research methods 52, pp. 455–463.

[86] Hoang D. (2019), How to build vr ui's with unity and oculus rift, part 2. URL: https://arvrjourney.com/how-to-build-vr-uis-with-unity-and-oculus-rift-part-2-69e31b32dd82.

[87] (2021), Introducing oculus air link, a wireless way to play pc vr games on oculus quest 2, plus infinite office updates, support for 120 hz on quest 2, and more. URL: https://www.oculus.com/blog/introducing-oculus-air-link-a-wireless-way-to-play-pc-vr-games-on-oculus-quest-2-plus-infinite-office-updates-support-for-120-hz-on-quest-2-and-more/.

[88] Anthes C., García Hernandez R., Wiedemann M. & Kranzlmüller D. (2016) State of the art of virtual reality technologies. pp. 1–19.

[89] Hall L., Paracha S., Mitsche N., Flint T., Stewart F., MacFarlane K., Hagan-Green G. & Dixon-Todd Y. (2022) When will immersive virtual reality have its day? challenges to ivr adoption in the home as exposed in studies with teenagers, parents and experts. PRESENCE: Virtual and Augmented Reality , pp. 1–74.

[90] Zhang H. (2017) Head-mounted display-based intuitive virtual reality training system for the mining industry. International Journal of Mining Science and Technology 27, pp. 717–722.

[91] Bowman D.A. & McMahan R.P. (2007) Virtual reality: how much immersion is enough? Computer 40, pp. 36–43.

[92] Fang C.M. & Harrison C. (2021) Retargeted self-haptics for increased immersion in vr without instrumentation. In: The 34th Annual ACM Symposium on User Interface Software and Technology, pp. 1109–1121.

[93] Suomalainen M., Mimnaugh K.J., Becerra I., Lozano E., Murrieta-Cid R. & LaValle S.M. (2021) Comfort and sickness while virtually aboard an autonomous telepresence robot. In: International Conference on Virtual Reality and Mixed Reality, Springer, pp. 3–24.

[94] Checa D. & Bustillo A. (2020) A review of immersive virtual reality serious games to enhance learning and training. Multimedia Tools and Applications 79, pp. 5501–5527.

[95] Samadbeik M., Yaaghobi D., Bastani P., Abhari S., Rezaee R. & Garavand A. (2018) The applications of virtual reality technology in medical groups teaching. Journal of advances in medical education & professionalism 6, p. 123.

[96] Javaid M. & Haleem A. (2020) Virtual reality applications toward medical field. Clinical Epidemiology and Global Health 8, pp. 600–605.

[97] Cai Y., Van Joolingen W., Walker Z. et al. (2019) VR, Simulations and serious games for education. Springer.

[98] Dechsling A., Orm S., Kalandadze T., Sütterlin S., Øien R.A., Shic F. & Nordahl-Hansen A. (2021) Virtual and augmented reality in social skills interventions for individuals with autism spectrum disorder: A scoping review. Journal of autism and developmental disorders , pp. 1–16.

[99] Oyelere S.S., Bouali N., Kaliisa R., Obaido G., Yunusa A.A. & Jimoh E.R. (2020) Exploring the trends of educational virtual reality games: a systematic review of empirical studies. Smart Learning Environments 7, pp. 1–22.

[100] Boletsis C., Cedergren J.E. & Kongsvik S. (2017) Hci research in virtual reality: A discussion of problem-solving. In: International Conference on Interfaces and Human Computer Interaction, IHCI 2017, Portugal, 21–23 July 2017.

[101] Bracq M.S., Michinov E., Arnaldi B., Caillaud B., Gibaud B., Gouranton V. & Jannin P. (2019) Learning procedural skills with a virtual reality simulator: An acceptability study. Nurse education today 79, pp. 153–160.

[102] Lu A., Chan S., Cai Y., Huang L., Nay Z.T. & Goei S.L. (2018) Learning through vr gaming with virtual pink dolphins for children with asd. Interactive Learning Environments 26, pp. 718–729.

[103] Irom B. (2018) Virtual reality and the syrian refugee camps: Humanitarian communication and the politics of empathy. International Journal of Communication 12, p. 23.

[104] John B.S. & Martin S. (2020) Using virtual reality for peace building in refugee camps of northern uganda. Frameless 3, p. 13.

[105] Oyekoya O., Urbanski J., Shynkar Y., Baksh A. & Etsaghara M. (2021) Exploring first-person perspectives in designing a role-playing vr simulation for bullying prevention: A focus group study. Frontiers in Virtual Reality , p. 127.

[106] Martingano A.J., Hererra F. & Konrath S. (2021) Virtual reality improves emotional but not cognitive empathy: A meta-analysis .

[107] Louie A.K., Coverdale J.H., Balon R., Beresin E.V., Brenner A.M., Guerrero A.P. & Roberts L.W. (2018), Enhancing empathy: a role for virtual reality?

[108] Embøl L., Hutters C., Junker A., Reipur D., Adjorlu A., Nordahl R. & Serafin S. (2021) Hearmevirtual reality: Using virtual reality to facilitate empathy between hearing impaired children and their parents. Frontiers in Virtual Reality , p. 77.

[109] Shashkevich A. (2018), Virtual reality can help make people more empathetic. URL: https://news.stanford.edu/2018/10/17/virtual-reality-can-help-make-people-empathetic/.

[110] Abadia R., Calvert J. & Dasika R. (2019) Effectiveness of using an immersive and interactive virtual reality learning environment to empower students in strengthening empathy and mastery learning. In: 27th International Conference on Computers in Education, ICCE 2019, Asia-Pacific Society for Computers in Education, pp. 495–504.

[111] McEvoy K.A. (2015) Through the eyes of a bystander: Understanding VR and video effectiveness on bystander empathy, presence, behavior, and attitude in bullying situations. Ph.D. thesis, Virginia Tech.

[112] Asher T., Ogle E., Bailenson J. & Herrera F.F. (2018) Becoming homeless: a human experience. In: ACM SIGGRAPH 2018 virtual, augmented, and mixed reality, pp. 1–1.

[113] Bailenson J. (2018) Experience on demand: What virtual reality is, how it works, and what it can do. WW Norton & Company.

[114] Schutte N.S. & Stilinović E.J. (2017) Facilitating empathy through virtual reality. Motivation and emotion 41, pp. 708–712.

[115] Braun V. & Clarke V. (2012) Thematic analysis. .

[116] Caulfield J. (2019), How to do thematic analysis. a step-by-step guide & examples. scribbr.

[117] Technologies U. (2021), Xr plugin management. URL: https://docs.unity3d.com/Manual/com.unity.xr.management.html.

[118] McHenry K. & Bajcsy P. (2008) An overview of 3d data content, file formats and viewers. National Center for Supercomputing Applications 1205, p. 22.

[119] Martin M. (2020), Optimize lighting for mobile games. URL: https://unity.com/how-to/advanced/optimize-lighting-mobile-games#lighting-challenges-mobile.

[120] Technology U. (2020), Canvas: Unity ui: 1.0.0. URL: https://docs.unity3d.com/Packages/com.unity.ugui@1.0/manual/UICanvas.

[121] Hsu H. & Lachenbruch P.A. (2014) Paired t test. Wiley StatsRef: statistics reference online .

[122] Bhandari P. (2022), An easy introduction to deductive reasoning. URL: https://www.scribbr.com/methodology/deductive-reasoning/.

[123] von Knorring J., Semb O., Fahlström M. & Lehti A. (2019) “it is through body language and looks, but it is also a feeling”-a qualitative study on medical interns’ experience of empathy. BMC Medical Education 19, pp. 1–8.

[124] DeJonckheere M. & Vaughn L.M. (2019) Semistructured interviewing in primary care research: a balance of relationship and rigour. Family medicine and community health 7.

[125] Crowe L., Butterworth P. & Leach L. (2016) Financial hardship, mastery and social support: Explaining poor mental health amongst the inadequately employed using data from the hilda survey. SSM-Population health 2, pp. 407–415.

[126] Crowe L. & Butterworth P. (2016) The role of financial hardship, mastery and social support in the association between employment status and depression: results from an australian longitudinal cohort study. BMJ open 6, p. e009834.

[127] Brondolo E., Brady ver Halen N., Pencille M., Beatty D. & Contrada R.J. (2009) Coping with racism: A selective review of the literature and a theoretical and methodological critique. Journal of behavioral medicine 32, pp. 64–88.

[128] Pierce C.S. & Scherra E. (2004) The challenges of data collection in rural dwelling samples. Online Journal of Rural Nursing and Health Care 4, pp. 25–30.

[129] Wilkins C.H. (2018) Effective engagement requires trust and being trustworthy. Medical Care 56, p. S6.

[130] Sim J. & Waterfield J. (2019) Focus group methodology: some ethical challenges. Quality & Quantity 53, pp. 3003–3022.

[131] Sinclair S., Beamer K., Hack T.F., McClement S., Raffin Bouchal S., Chochinov H.M. & Hagen N.A. (2017) Sympathy, empathy, and compassion: A grounded theory study of palliative care patients' understandings, experiences, and preferences. Palliative medicine 31, pp. 437–447.

[132] McCambridge J., Kypri K. & Elbourne D. (2014) Research participation effects: a skeleton in the methodological cupboard. Journal of clinical epidemiology 67, pp. 845–849.

[133] Newington L. & Metcalfe A. (2014) Factors influencing recruitment to research: qualitative study of the experiences and perceptions of research teams. BMC medical research methodology 14, pp. 1–11.

[134] Cobb S.V., Nichols S., Ramsey A. & Wilson J.R. (1999) Virtual reality-induced symptoms and effects (vrise). Presence: Teleoperators & Virtual Environments 8, pp. 169–186.

[135] Sharples S., Cobb S., Moody A. & Wilson J.R. (2008) Virtual reality induced symptoms and effects (vrise): Comparison of head mounted display (hmd), desktop and projection display systems. Displays 29, pp. 58–69.

[136] Yao R., Heath T., Davies A., Forsyth T., Mitchell N. & Hoberman P. (2014) Oculus vr best practices guide. Oculus VR 4, pp. 27–35.

[137] Kern A.C. & Ellermeier W. (2020) Audio in vr: effects of a soundscape and movement-triggered step sounds on presence. Frontiers in Robotics and AI 7, p. 20.

[138] Oh H. & Son W. (2022) Cybersickness and its severity arising from virtual reality content: A comprehensive study. Sensors 22, p. 1314.

[139] Sidenmark L., Kiefer N. & Gellersen H. (2019) Subtitles in interactive virtual reality: Using gaze to address depth conflicts. In: Workshop on Emerging Novel Input Devices and Interaction Techniques.

[140] Kao D., Ratan R., Mousas C., Joshi A. & Melcer E.F. (2022) Audio matters too: How audial avatar customization enhances visual avatar customization. In: CHI Conference on Human Factors in Computing Systems, pp. 1–27.

[141] Hébert S., Béland R., Dionne-Fournelle O., Crête M. & Lupien S.J. (2005) Physiological stress response to video-game playing: the contribution of built-in music. Life Sciences 76, pp. 2371–2380. URL: https://www.sciencedirect.com/science/article/pii/S0024320505000378.

[142] Ekman I. (2013) On the desire to not kill your players: Rethinking sound in pervasive and mixed reality games. In: FDG, pp. 142–149.

[143] Keehl O. & Melcer E. (2019) Radical tunes: exploring the impact of music on memorization of stroke order in logographic writing systems. In: Proceedings of the 14th International Conference on the Foundations of Digital Games, pp. 1–6.

[144] Larsson P., Väljamäe A., Västfjäll D., Tajadura-Jiménez A. & Kleiner M. (2010) Auditory-induced presence in mixed reality environments and related technology. In: The engineering of mixed reality systems, Springer, pp. 143–163.

[145] Nacke L.E. & Grimshaw M. (2011) Player-game interaction through affective sound. In: Game sound technology and player interaction: Concepts and developments, IGI global, pp. 264–285.

[146] Lausen A. & Schacht A. (2018) Gender differences in the recognition of vocal emotions. Frontiers in psychology 9, p. 882.

[147] Loughran T., Mahoney K. & Payling D. (2021) Women's voices, emotion and empathy: engaging different publics with 'everyday'health histories. Medical Humanities .

[148] Wilton P., Neville D., Audas R., Brown H. & Chafe R. (2015) An evaluation of in-person and online engagement in central newfoundland. Healthcare Policy 11, p. 72.

[149] Shapka J.D., Domene J.F., Khan S. & Yang L.M. (2016) Online versus in-person interviews with adolescents: An exploration of data equivalence. Computers in human behavior 58, pp. 361–367.

[150] Vasileiou K., Barnett J., Thorpe S. & Young T. (2018) Characterising and justifying sample size sufficiency in interview-based studies: systematic analysis of qualitative health research over a 15-year period. BMC medical research methodology 18, pp. 1–18.

[151] Dworkin S.L. (2012), Sample size policy for qualitative studies using in-depth interviews.

[152] Boddy C.R. (2016) Sample size for qualitative research. Qualitative Market Research: An International Journal .

[153] Simmons A. (2018) The disadvantages of a small sample size. Retrieved from .

9. APPENDICES

Appendix 1 Finnish Interview Template

Section I: The VR Experience and Experiment

1. *Ensivaikutelmat VR-demosta?*
2. *Oliko VR-kokemus uskottava?*
3. *Tekikö VR-kokemus mielestäsi sen mitä sen pitäisi tehdä?*
4. *Mitä pitäisi muuttaa tai korjata kokeessa?*

Section II: Reflection on the Stories

1. *Mitkä avatarien tarinat muistat parhaiten? Miksi?*
2. *Oliko tarinoissa jotain informaatiota, joka oli sinulle uutta?*
3. *Mitä ajattelet sinulle esitetyistä tarinoista ylipäätään?*

Section III: Influence on Empathy

1. *Mitä ajattelet näistä vaikeuksista joita kansainväliset opiskelijat kohtaavat yliopistossa?*
2. *Mitä ensivaikutelmia ja ajatuksia sinulla oli tarinoista jotka esitettiin sinulle virtuaalitodellisuudessa?*
3. *Miten sinun reaktiosi olisi jos jotain samanlaista tapahtuisi sinulle? Eli mitä jos kansainvälinen opiskelija puhuisi sinulle tosielämässä samankaltaisista haasteista kuin VR-kokeessa esitettiin.*

Section IV: Benefits, Technology, and Going Forward

1. *Koitko tämän kokemuksen olevan hyödyllinen sinulle tai muille, kansainvälisten opiskelijoiden vaikeuksista oppimiseksi?*
2. *Kenelle tällaiset VR-kokeet, pidmemälle kehitettynä, voisivat olla hyödyllisimpiä?*
3. *Millä tavoin teknologiaa voi käyttää vaikeiden asioiden kommunikoimiseksi, isolle yleisölle?*