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ORIGINAL PAPER

INCREASING AWARENESS AND EMPATHY AMONG UNIVERSITY STUDENTS THROUGH IMMERSIVE EXERCISES – TESTING OF THE VIRTUAL REALITY APPLICATION: A PILOT STUDY

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Abstract

Background: This paper presents an overview of a pilot study focused on testing the effectiveness of immersive virtual reality (VR) exercises, within extended reality experiences, in increasing awareness and empathy among university students towards pregnant women, elderly people, people in wheelchairs, and people with some sort of sight impairment. The extended reality experience was designed to simulate various scenarios that reflect the experiences of people from diverse backgrounds, to promote a better understanding of different perspectives and social issues related to some of the challenges tackled by people whose limitations are many times overlooked. **Material and Methods:** A design-based research methodology was applied and qualitative and quantitative data were collected in samples of 20 students from 3 countries. **Results:** Overall, the results suggest that immersive VR applications can be an effective tool in increasing awareness and empathy among higher education students. The use of VR technology can create a sense of presence and immersion that allows students to experience situations that they may not have encountered otherwise. The results attained with the immersive experiences have provided evidence that these solutions can foster a greater understanding of different perspectives and promote empathy towards individuals from diverse backgrounds. **Conclusions:** Ongoing research correlated with the Mixed Reality on Universal Design's Secret Service (Mr. UD) project results is already expanding on these findings by testing the effectiveness of VR applications in different contexts and with larger and more diverse samples. Additionally, the research conducted has provided relevant evidence that suggests that VR applications and their inclusion in training programs may help promote behavior change and reduce prejudice and discrimination towards marginalized groups. Med Pr. 2023;74(3):187–97

Key words: virtual reality, immersion, universal design, empathy, higher education, extended reality

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INTRODUCTION

Testing is a crucial stage of any design process. In the case of virtual reality (VR), it allows to provide high-quality VR products and experiences. As VR technology has been developing in various areas with incredible speed, there are new challenges for VR developers and creators concerning verification, validation and testing activities [1]. Testing of VR applications can be considered in several areas, including usual software testing and usability testing. For educational purposes, VR products should provide learning value [2]. Therefore, additional tests are added to check the achievements and progress of students in particular subjects and topics. On the other hand, usability testing focuses on how users use the system, i.e., how easy and quickly they accomplish tasks, how many and what errors they make, how easy they get proficiency, and how pleasurable it is to use the system by users [3,4]. Regardless of the type of testing implemented, this is a stage aimed at improving the VR system in a given context.

Over the last quarter of a century, the term "empathy" as a conceptual construct has become the subject

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of interest in the humanities and social sciences – pedagogy, psychology, anthropology, and philosophy. Nowadays, in the face of the growing problem of the lack of effective interpersonal communication and mutual understanding of individuals and groups of people, attempts are being made to search for new solutions also in the fields of exact sciences and engineering.

Empathy researchers generally agree that empathy is one of the key personality factors that make it easier for a person to establish and maintain good interpersonal relationships, and thus improve social functioning and well-being of the individual [5]. Empathic competencies are associated with the ability to "emotional harmony," compassion and care for other people, and understanding their feelings and point of view. Despite the multitude of definitions, their common feature is the focus on the active interest of a person who shows high empathy for other people's needs, motivations, or problems. The literature on the subject talks about "empathic motivation" [6], i.e., the ability to look at a given situation from someone else's perspective and, consequently, to experience appropriate emotions that lead to actions aimed at improving the situation of other people, or even a closely related with the empathy of an "altruistic personality" [7]. Empathy, as one of the key features of this type of personality, is a predictor of pro-social activity in many areas of our lives. Another empathy researcher, Hoffman [8,9], combines empathy with being sensitive to the needs of other people, respecting their dignity, and observing the principles of social justice. Hoffman postulates that at the highest level of complexity, emotional empathic reactions arise due to the ability to assume someone else's role, and thus are a consequence of cognitive empathic processes. This combination of cognitive and emotional components enables an individual to react adequately to the suffering of another person, showing compassion and helping them.

Empathy is a crucial element in the engineers' education as well. The importance of it has become more and more underlined. The concept of implementing user in the design process is well-known in such methodologies as, design thinking, user-centred design, and human-centered design. The abilities of a future engineer should be extended by empathy-related abilities, which allow them to have wider perspectives and create valuable products and services. Nowadays, it is also essential to include aspects of inclusion, equality, social responsibility and awareness. The universal design concept is about the intentional design to build such an environment that it is accessible to most people, regardless of their disability, age, gender or other obstacles [10–12]. The VR can be considered an effective tool for training empathy-related abilities. The VR simulates the experience of a designed challenging situation in a non-real environment, in first-person point of view. Therefore, it provides a safe training environment and a possibility for learning while experiencing something unusual for a user in the real world.

In this article, the authors focus on the impact of the VR exercises on the level of empathy among participants of the pilot study and changing their approach to people with disabilities and various physical limitations. Moreover, the carried testing sessions allowed to gather valuable user feedback to improve the final version of the VR application and elaborate tasks in the created virtual environment.

Related work

Mr. UD context

The Mixed Reality on Universal Design's Secret Service (Mr. UD) project has been conducted within the context of an Erasmus+ initiative (Erasmus+ Strategic Partnership Higher Education Sector). The main objective of this project is to enhance the expertise of upcoming engineers, educators, and designers in the domain of universal design by delivering a collection of functional pedagogical instruments founded on extended reality (XR). These instruments aim to foster a deeper comprehension of the diverse accessibility requirements. The extended reality exercises generated within this project allow users to undergo hypothetical predicaments faced by individuals with disabilities, thus enabling them to alter their perspectives. The project presents 5 augmented reality tasks that focus on various aspects related to disabilities or limitations, such as visual impairment, autism spectrum disorder, mobility constraints, pregnancy-related difficulties, and age-related challenges. To simulate some of the issues experienced by users in the aforementioned categories, a virtual supermarket environment was developed. Although shopping is a familiar experience for most individuals, the VR tasks, which are enhanced by peripheral devices like pregnancy simulators, geriatric suits, and wheelchairs, offer an extensive user perspective and may enhance user empathy in real-life situations.

Furthermore, the VR tasks underwent validation by experts, underscoring the innovative nature of this line of inquiry which is centred on the systematic and formal examination of the potential to integrate empathy mechanisms into XR tools. These tools are designed to raise awareness among different audiences, including

stakeholders involved in the creation process and design of public physical spaces. While empathic design has been previously explored, the utilization of VR and XR as empathy development strategies are still largely unexplored, making this study all the more significant. Notably, this study has also prioritized populations from geographically distant countries, thereby facilitating the exploration of the impact of cultural factors on empathy development and formation.

Virtual reality and emotion

It is not possible to establish a relationship between VR and emotion without understanding the various dimensions of immersion that the user experiences when interacting with immersive and interactive environments. The great potential of VR is generally best known for the strong feeling of presence and verisimilitude with the physical space that it causes in the user, and this phenomenon is called perceptual immersion. Currently, head mounted devices (HMD) have several types of sensors that guarantee high-performance tracking, and high-resolution graphics systems, providing a fluid perceptive experience both from the visual point of view and from the vestibular system [13].

These forms of illusion, despite being fundamental in making VR special from another type of media, are not the only means of instilling in the user a feeling of psychological presence. According to Adams [14], autonomously from purely perceptive immersion, in narrative immersion the user creates emotional and affective connections with the characters, and for that reason feels involved in a story.

In the wake of Janet Murray [15] and based on the analogy of the HoloDeck virtual reality environment, Ryan [16] deepens the narrative immersion, relating it to the concept of agency and interactivity. For this author, contrary to ludic immersion in which the user is absorbed in performing the task, in narrative immersion there is "an engagement of the imagination in the mental construction and contemplation of a story world", and this can take 3 forms: spatial, temporal and emotional [16].

The contribution of these authors is considered a landmark because they established a direct connection between the concepts of immersion, emotion and storytelling in virtual environments. More than producing 3-dimensional scenarios with a high degree of realism, in VR it is also important to create mechanisms of empathy between the user and the characters, and ludic situations, to intensify the degree of immersion in its different dimensions.

A key point in VR environments for promoting a feeling of greater immersiveness and involvement is reflected in the quality of the interactivity model presented to users by the system. The concept of agency, close to the term effectance in psychology, consists of the user's ability, as a result of interaction with the virtual environment, to modify the course of the narrative, actions and activities carried out in it. This type of interaction creates a strong sense of participation and autonomy in the user [17].

There are several theories and theoretical models about the concept of experience that seek to model the user's emotional states in an interactive and playful environment. Some of these models have been discussed in the context of VR.

The self-determination theory (SDT), based on the assumption that users have 3 basic needs, namely: competence, relatedness and autonomy, has served as a framework for studies applied to emotions in VR [18]. The Attention, Relevance, Confidence, Satisfaction (ARCS) Model, has been used in VR as a basis for evaluating user motivation and emotional involvement in virtual environments for educational purposes [19,20]. One of the most popular psychology theories among researchers of games, and simulation environments is Csikszentmihalyi's theory of flow and optimal experience, proposed in 1975 and extended in 1988 [21]. Flow theory offers a solid framework based on empirical data for the development of interactive simulations, predicting the user's mental states taking as input his level of expertise and the level of difficulty of the task.

As in all subgenres that make up the universe of digital media, and VR is no exception, Norman's contribution to a theory of experience in human–computer interaction is unavoidable. At the base of emotional design and experience design [22] was the work that paved the way for the user-centred design approach [23], which, for the first time in a systematic way, incorporated the contributions of cognitive psychology in software development frameworks. The importance of the human cognition model for VR, based on Norman's contribution, composed of the various levels of cognitive response – visceral, behavioural, reflective, and emotional processes, is analysed in [13].

Empathy and emotion are key to understanding user behaviour and engagement in immersive VR environments. In fact, Cadet and Chainay [24] show how memory, immersiveness and the feeling of presence are strongly influenced by emotions. Conversely, and in line with the present research work by Schutte and

Stilinović [25], they investigated how the VR experience generated empathy in public participation when compared to other media with less perceptive immersion.

Virtual reality and empathy

Many methods of measuring empathy in psychology focus on its cognitive or emotional nature. An attempt at a holistic, broad understanding of the phenomenon of empathy was made by Davis, who defined it as a set of processes (affective and non-affective) occurring in the observer in reaction to the experiences of other people [26].

In 1980, this author developed the *Interpersonal Reactivity Index* (IRI) as a multidimensional method of measuring empathic skills [27,28]. In this tool, he distinguished several personality areas of empathic dispositions, included in 4 scales:

- *Perspective-taking scale* – reflecting the ability and tendency to take someone else's point of view in everyday life situations;
- *The empathic care scale* – refers to the tendency to feel compassion and sympathy towards people in difficult situations;
- *The scale of personal distress* – measuring the tendency to experience negative emotions in response to the suffering of other people;
- *Fantasy scal*e – which concerns the ability to imaginatively transfer oneself into fictitious situations.

In the pilot study, the theoretical assumptions of Davis's empathy measurement were implemented to investigate the transition in the empathy-related abilities and students' approach. The questions in pre and post-tests were constructed based on the assumptions of the 4 scales of the Davis IRI questionnaire.

MATERIAL AND METHODS

Participants

The created VR experiences were tested by students from 4 universities: Lodz University of Technology (Poland), Polytechnic of Porto (P.Porto) (Portugal), University of Aveiro (Portugal), and University of Tartu (Estonia) during the International Summer School organized by P.Porto in September 2022. The participants were recruited by all 4 institutions using dissemination posters. Twenty students (5 from each university) were selected based on their final score in the recruitment process. The participants attended first-cycle (Bachelor's), second-cycle (Master's) and doctoral studies.

The participants' average age and self-evaluation of VR experience is presented in Table 1.

All the participants have had previous experiences connected with VR, mainly of the entertainment nature.

Tested virtual reality experiences

The pilot study covers the testing sessions of 4 VR exercises named as follows:

1) pregnancy,
2) elderly people,
3) wheelchair user,
4) sight impairments.

All the exercises in VR were in alpha versions and contained the basic concepts elaborated in the frame of the Mr. UD project. The virtual environment was presented with the use of Oculus Quest VR headsets. Original concepts of the exercises have been published in previous work by the authors [29].

The exercise "Pregnancy" was based on the challenges that a pregnant woman may face in daily activities during shopping. The tasks concerned general fatigue, limited manoeuvrability and dietary restrictions. The testers were placed in the virtual supermarket, and they wore the pregnancy belly suit to better simulate the limited movements and additional weight during the pregnancy, especially the last trimester of it (Figure 1).

In the exercise "Elderly people" the students faced challenges tackled by the elderly when shopping in the supermarket. Due to wearing a geriatric suit with additional movement limiters, the users had the problem of moving around the store, reaching for heavy goods from low and high shelves, reading labels written

Table 1. Participants – students from 4 universities (Porto, Portugal, September 2022)

Variable	Participants (N = 20)	
	male (N = 12)	female (N = 8)
Age [years] (M±SD)	26.3±5.7	22.6±1.4
Self-evaluation of VR experience (scale 1–5) (M±SD)	3.5±0.6	2.75±0.7

Figure 1. A participant of the International Summer School doing the "Pregnancy" exercise

in small print, and understanding speech in loud surroundings (Figure 2).

The exercise "Wheelchair user" allowed testers to put themselves in the place of any person who uses a wheelchair to move around during the day in various surroundings, including such places as a shop. Considering mobility impairments, the exercise included such challenges as large volume obstacles in corridors, products placed on top shelves, and narrow spaces between aisles and cash-out registers which do provide not enough space for a wheelchair to pass (Figure 3).

The aim of the exercise "Sight impairments" was to simulate the problem of vision that is affecting more than 2.2 billion people worldwide and presents a growing trend in the modern population [30]. The students experienced how to move around in space when they barely saw the objects. They could feel the confusion and huge difficulties in performing a seemingly simple task. The first part of the exercise was about performing simple

Figure 2. A student in the age simulator performing the "Elderly people" exercise with an instructor

Figure 3. Testing of the "Wheelchair user" exercise

tasks in the kitchen (Figure 4), and the second one was simulated with the VR headset in the supermarket.

Testing procedure

The procedure consisted of a few stages: basic demographic data questionnaire, empathy pre-test, the performance of VR experience, empathy post-test, and interview. The procedure is presented in Figure 5.

Based on the theoretical assumptions of Davis's empathy measurement (mentioned in the previous

Figure 4. The first part of the "Sight impairments" exercise was performed by students

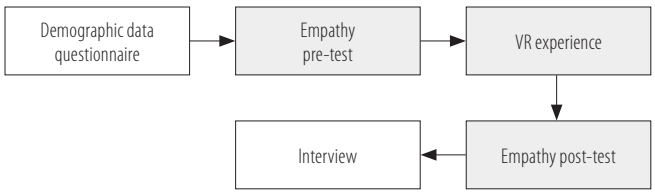

Figure 5. The testing procedure was implemented during the International Summer School in Porto, Portugal

section), a tool in the form of pre-and post-tests was constructed to investigate the increase in students' empathy. The empathy pre-and post-tests were elaborated for the alpha versions of VR exercises prepared for the Summer School at P.Porto, Portugal. The sets of statements are shown in Table 2. The main aim of the tests was to check possible changes in attitude among the participants towards people with some special needs after the immersion in their position.

The interviews with the summer school participants covered general feedback about the exercises and some questions concerning usability and users' ability to perform the tasks. The students gave their answers to the following questions:

- What was the most surprising thing you experienced during immersion exercises? How did you feel?
- What problems did you encounter during experiments?
- What are the limitations of simulations?

Table 2. The statements in the empathy pre-and post-tests

Exercise	Statements	
	pre-test	post-test
"Pregnancy"	I can put myself in the shoes of a pregnant woman. I do not understand why I should let a pregnant woman through in a queue. I can predict what may be difficult for pregnant women. When I see a pregnant woman I become more caring.	I can put myself in the shoes of a pregnant woman. I do not understand why I should let a pregnant woman through in a queue. I can predict what may be difficult for pregnant women. I better understand the problems of pregnant women. My perception of pregnant women has changed. I care more about problems of pregnant women.
"Elderly people"	Usually, I do not know how to deal with an elder person. Elder people evoke negative emotions in me. I can put myself in the shoes of an elder person. I willingly help elder people. I do not understand why I should give place to an elder person.	I can predict what may be difficult for elder people. My perception of elder people has changed. I can put myself in the shoes of an elder person. I care more about elder people's problems. I do not understand why I should give place to an elder person.
"Wheelchair user"	I would spontaneously help a person who uses a wheelchair. People who use wheelchair arouse negative emotions in me. I can predict how a wheelchair user will feel in certain situations. It is difficult for me to assess whether I behave properly towards people who use a wheelchair. I can put myself in the shoes of a wheelchair user.	I can predict how a wheelchair user will feel in certain situations. I can put myself in the shoes of a wheelchair user. People who use wheelchair arouse negative emotions in me. My perception of people using wheelchair has changed. I would spontaneously help a person who uses a wheelchair.
"Sight impairments"	I think that people with vision disorders (excluding the blind), thanks to the development of medicine and technology, do not experience any life limitations. People with vision disorders can function just as well as people without these disorders. I think that some of vision disorders can make it difficult to carry out daily activities. I can put myself in the shoes of a person with vision disorder. I can predict what may be difficult for a person with vision disorder.	I can predict what may be difficult for a person with vision disorder. I think that vision disorders do not indicate someone's disability. People with vision disorders can function just as well as people without these disorders. I can put myself in the shoes of a person with vision disorder. I think that some of vision disorders can make it difficult to carry out daily activities. My perception of people with vision disorders has changed.

- What should be changed in the environment and why?
- How much did your experiences in the virtual environment seem consistent with your real-world experiences?
- How realistic was the VR environment of the supermarket?
- How involved were you in the virtual environment experience?
- What kind of help/support is needed according to you?

Additionally, the observations were done by the mentors during the testing sessions and all insights were noted down.

RESULTS

The results of the empathy tests from the exercises are presented in Table 3.

Thanks to interviews with the students, it was possible to evaluate the immersion experiences and given tasks.

The tested VR environment was in the preliminary version. Therefore, the testers pointed out several aspects that need to be improved in the final version. First of all, the number of products should be increased. Not enough items gave the impression of emptiness, and it is not very real. According to the testers, other refinements can be done in such issues as the colour of the shelves, price tags and the inclusion of people – other customers and proper sounds that imitate better the reality of the supermarket. The arrangement of products was evaluated poorly, which was mentioned by many of the students and impacted their level of immersion. The involvement in the virtual environment was assessed by grade 2.9 on a 5-step scale (±0.7). The biggest destructors were "too" simplified shop with an unrealistic arrangement of the products, problems with the boundaries of the virtual world, and no additional sensory stimuli (sound, haptics from controllers).

The use of additional equipment such as a geriatric suit, pregnancy belly or a wheelchair was said to be a valuable element of the exercises and allowed testers to put themselves in the shoes of other people.

Some comments on the exercises are shown in Table 4.

DISCUSSION

The authors may affirm that the users participating in the tests left the sessions with a completely different view towards the challenges tackled by the personas simulated in the XR experiences provided. As opposed to simply discussing and attempting to imagine what pregnant women, elderly people, people in wheelchairs, and people with some sort of sight impairment go through, the participants in the test were invited to place themselves in these people's shoes. The answers collected in the pre- and post-test questionnaire provided evidence that there were noticeable changes in the participants' empathy and awareness towards some barriers that before the experience had never crossed their minds.

The differences in the answers provided in the pre- and post-questionnaire widely varied with some increasing by almost 1-point grade, for instance, in the case of the participant's ability to perceive and predict the limitations felt by users with vision disorders. It was curious to notice that participants considerably changed their perception regarding the ability to embody or predict the problems dealt with by elderly people (+0.9 pts), people in wheelchairs (+1.05 pts), and people with some sort of sight impairment (+0.8 pts), but not as much when predicting the problems felt by pregnant women (+0.1 pts).

It is also worth outlining that there was an overall above-average positive empathic attitude towards the problems felt by all the personas simulated. However, some of the results show that there is still room for improvement regarding simple things such as giving up your seat to an elderly person or improving attitudes towards pregnant women. The test results demonstrate that XR experiences such as the ones developed may be used as useful tools for changing mentalities and attitudes.

The research team was also able to collect valuable information and feedback regarding possible improvements and evident flaws in the XR experiences tested. The tests conducted also enabled the research team to evaluate the test protocol setup. The inclusion of an instructor was recognized as a positive add-on for it enable quick and just-in-time problem-solving and promoted a fluid think-aloud interaction between the participant and the instructor. It is worth mentioning that all instructors were clearly instructed to not intervene in any moment apart from hardware or software problem issues unsolvable by the participant. Information collected allowed the research team to fine-tune and improve the test protocol in matters related to test onboarding, as well as activity and participant interaction flow. What was learned has since been used in other test activities conducted by the Mr. UD team.

Last, but not least, specific hardware and software problems and possible improvements outlined by

Table 3. The summary of the results of the empathy tests

Question	Results [pts]	
	pre-test	post-test
"Pregnancy"		
I can put myself in the shoes of a pregnant woman.	2.7	3.95
I do not understand why I should let a pregnant woman through in a queue.	2.35	2.4
I can predict what may be difficult for pregnant women.	3.6	3.7
When I see a pregnant woman I become more caring.	3.7	
I better understand the problems of pregnant women.		4.21
My perception of pregnant women has changed.		3.9
I care more about problems of pregnant women.		3.7
"Elderly people"		
Usually, I do not know how to deal with an elder person.	2.7	
Elder people evoke negative emotions in me.	2.1	
I can put myself in the shoes of an elder person.	3.1	4.0
I willingly help elder people.	4.0	
I do not understand why I should give place to an elder person.	1.6	1.71
I can predict what may be difficult for elder people.		3.8
My perception of elder people has changed.		3.64
I care more about elder people's problems.		3.71
"Wheelchair user"		
I would spontaneously help a person who uses a wheelchair.	3.48	3.87
I can predict how a wheelchair user will feel in certain situations.	2.7	3.75
I can put myself in the shoes of a wheelchair user.	2.85	3.7
It is difficult for me to assess whether I behave properly towards people who use a wheelchair.	3.29	
People who use wheelchair arouse negative emotions in me.	1.7	1.8
My perception of people using wheelchair has changed.		4.3
"Sight impairments"		
I think that people with vision disorders (excluding the blind) do not experience any life limitations.	2.4	2.6
People with vision disorders can function just as well as people without these disorders.	2.55	2.53
I think that some of vision disorders can make it difficult to carry out daily activities.	4.2	4.4
I can put myself in the shoes of a person with vision disorder.	3.2	4
I can predict what may be difficult for a person with vision disorder.	3.17	4.13
My perception of people with vision disorders has changed.		3.9

the users were taken note of and were provided to the development team for reviewing and implementation.

CONCLUSIONS

The research presented provided insight into the testing sessions conducted with the participation of international higher education students during Mr. UD Summer School at P.Porto in Portugal in 2022. Twenty testers evaluated the alpha version of the VR environment, the supermarket, and 4 different exercises – "Pregnancy," "Elderly people," "Wheelchair user" and "Sight impairments." This study and the test conducted introduced simulation tasks with an inherent education purpose by using XR experiences to address vision impairments, mobility impairments, pregnancy-related

Table 4. Students' comments on exercises

Exercise	Students' comment
"Pregnancy"	„I understand better how the centre of balance is shifted in pregnant women. Although for pregnancy the weight is added slowly over time so the body is also slowly accommodating to the weight and centre of mass shift." "The belly creates some restrictions only in abdominal area, so I suppose it is quite limited feeling of being pregnant."
"Elderly people"	"I understand a bit better how it may be difficult to take stuff from top and bottom shelf. Still, I don't feel the joint pain, low physical fitness or the mental state of an elderly person." "We were able to get a general idea of the difficulties that elderly person has in their day-to-day life. I felt some fear what awaits me with the elderly." "When I put on both geriatric suit and a pregnancy belt, I understood that life can never be easy in such circumstances."
"Wheelchair user"	"The biggest problem is to grasp the products from the top and bottom shelves. Probably people with such disabilities should always have a personal assistant." "In the app grasping distance is a problem - you can't get so close to easily grab things from the shelf. Maybe it would be more immersive experience when there will be objects of various size and weight at different height shelves." "It seems to us that picking up objects could be designed differently. It was challenging to go to the list and the shopping cart at the far end of the supermarket." "According to me any activity for a person in a wheelchair is a challenge."
"Sight impairments"	"For me the cataract simulation enhanced empathy towards my grandmother because she has this issue. The daltonism variants were also interesting and can probably increase empathy somewhat for people who have daltonic close ones, although the daltonic has lived like this from birth so cannot achieve 100% empathy." "Walking alone was the most difficult task, since even the shortest path felt like a marathon." "I felt discomfort, because vision is one of the most important senses that humans have."

issues, and age-related difficulties. The tasks conducted in a virtual supermarket setting, a familiar environment for most people, gave the experiences a relatable real-life context. Several tasks were enhanced by peripheral devices, such as a pregnancy simulator, a geriatric suit, and a wheelchair, to provide a more comprehensive user experience and enhance empathy.

The tasks were evaluated by higher education students from three different countries in that, after participating in the tests with the proposed XR exercises, which included both virtual and real devices, felt an increase in their empathy towards the profiles of users simulated in each experience. The technology provided a high level of immersion, allowing users to experience various human body limitations and develop a deeper understanding of the challenges posed by everyday activities. As a result, the participating higher education students were able to see things from a different perspective, which could lead to a more profound understanding of different situations. The results show that there was a change in the empathy of the participants towards the user personas simulated in the experiences. It is believed that this shift will influence the student's attitude towards people that face challenges in their life.

Future research will be focused on conducting user studies to determine whether the designed experiences are suitable for training and contributing to the enhancement of empathy and awareness in professionals such as future engineers and designers. Tapping into their creative process and naturally embedding proactive concerns with universal design would ultimately represent the purpose and usefulness of the type of XR solutions developed and tested in this study. Further development of the work already done will, however, need to increase the sample and diversity of the participants in the tests. In addition to the qualitative empathy evaluations that have already been conducted, the authors anticipate the possibility of investigating the use of biometric technologies, such as smartwatches and portable EEG technology, to collect quantitative physiologically based data correlative with empathy. All this data may also be thought out as worth trying to correlate with other demographic issues, such as gender or age, which would eventually shed additional light on hypothetical inter-influences between the simulations and specific target demographics.

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Statistical analysis: Anna Laska-Leśniewicz
Interpretation of results: Rui Raposo
References: Rui Raposo, Mario Vairinhos, Anna Laska-Leśniewicz, Joanna Sztobryn-Giercuszkiewicz

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