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REVIEW PAPER

ENHANCING EMPATHY THROUGH VIRTUAL REALITY: DEVELOPING A UNIVERSAL DESIGN TRAINING APPLICATION FOR STUDENTS

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Abstract

The lack of empathy towards disability is a significant societal issue that hampers inclusivity and understanding. Many struggle to comprehend the daily challenges and experiences faced by people with disabilities, leading to ignorance, prejudice, and exclusion. However, empathy plays a pivotal role in addressing this problem and serves as the foundation for developing and creating better products, services, and environments. This article explores the potential of developing virtual reality (VR) applications to enhance students' empathy towards individuals with disabilities. By increasing empathy levels, students are expected to gain significant qualifications in universal design (UD). The full application development process covers the most suitable head-mounted display (HMD) set. The implementation methodology using the Unity programming platform, the approach adopted for conducting classes using the developed VR application, and the deployment stage. Testing was successfully conducted on a student population, receiving positive user feedback. Through the integration of VR technology, the authors thoroughly describe how to address the empathy gap and equip students with essential skills for inclusive and accessible design. The findings presented in this study provide valuable guidance for educators and developers interested in harnessing VR's potential to foster empathy and advance universal design practices. With the presented methodology and proposed application, the authors demonstrate the effectiveness of VR applications in elevating students' empathy levels, consequently enhancing their qualifications in universal design. Med Pr. 2023;74(3):199–210

Key words: virtual reality, universal design, empathy, curriculum, surveys and questionnaires, computer simulation

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INTRODUCTION

The challenges of persons with disabilities can be effectively overcome by implementing universal design principles. Universal design aims to create products, environments, and services that are accessible and usable by people of all abilities, without the need for adaptation or specialised design. By incorporating a universal design, barriers are minimised or eliminated, ensuring equal access and participation for everyone. This approach involves considering a wide range of abilities and diverse needs from the outset of the design process. Universal design not only benefits individuals with disabilities but also enhances the overall user experience for all individuals, regardless of their age, size, or abilities.

However, the lack of empathy towards disability represents a significant societal shortcoming that undermines inclusivity and hinders progress. Many struggle to grasp the daily obstacles and experiences faced by people with disabilities, resulting in ignorance, bias, and marginalisation. However, empathy serves as a vital catalyst for change, forming the bedrock upon which better products, services, and environments can be developed. By embracing empathy, a profound understanding of the diverse needs and perspectives of individuals with disabilities is gained. This understanding fuels the creation of inclusive products that cater to a broader range of users, developing services that

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accommodate varying abilities, and establishing environments that prioritise accessibility and equal opportunities.

In this context, embracing universal design concepts, society can foster inclusivity and break down barriers, enabling persons with disabilities to fully engage in various aspects of life, including education, employment, transportation, and social participation.

In recent years, the transformative potential of virtual reality (VR) technology in education has gained significant attention. This scientific exploration delves into the exciting realm of utilising VR applications to enhance students' empathy towards individuals with disabilities. By immersing students in simulated environments that replicate the challenges faced by people with disabilities, the goal is to cultivate heightened levels of empathy, fostering a deeper understanding of universal design principles.

Drawing from real-world experiences in developing and implementing a VR application, this study offers valuable insights into this immersive technology's selection, development, and implementation. Choosing a suitable head-mounted display (HMD) set is examined, followed by a detailed account of the application's development using the Unity programming platform. An instructional approach is also outlined to facilitate effective and meaningful learning experiences.

It was deployed and tested on a group of students to evaluate the impact and effectiveness of the VR application. Preliminary results revealed positive feedback, reinforcing the potential of VR technology to bridge the empathy gap and foster inclusive attitudes among students.

This research significantly contributes to the growing knowledge on leveraging VR applications for empathy development in educational settings. By specifically addressing students' attitudes towards individuals with disabilities, it sheds light on the immense potential of VR to enhance their qualifications in universal design. The comprehensive examination of the HMD selection process, application development using Unity, and the instructional approach provides practical insights that educators and developers can utilise when implementing similar VR applications.

In summary, exploring VR applications to elevate students' empathy levels and enhance their qualifications in universal design offers promising prospects. The insights gained from real-world experiences shed light on VR application selection, development, and implementation. The positive feedback from users further underscores the potential of VR as a powerful tool for fostering student empathy.

RELATED WORK

This section provides a comprehensive review of the related literature concerning developing a VR application for training experiences aimed at teaching empathy to students in the context of later teaching universal design.

As highlighted in the literature, empathy plays a crucial role in universal design. The study by Watchorn et al. [1] presents an integrated literature review, emphasising the significance of empathy in understanding the needs and experiences of diverse users in the built environment. Similarly, Ovienmhada et al. [2] discuss the role of empathy in the inclusive design of decision support systems for environmental governance, demonstrating its importance in creating solutions that cater to the needs of all individuals.

Virtual reality applications have shown promise in facilitating the implementation of universal design principles. The study by Craig et al. [3] explores the effects of coaching on implementing Universal Design for Learning (UDL), including utilising VR applications. It examines how VR can enhance the learning experience and support the application of universal design principles in educational settings.

Effective teaching methods are crucial for promoting universal design principles among students. Baroni and Lazzari [4] discuss using technologies and blended learning methods in teaching universal design at the university level. Their work sheds light on the approaches that can be adopted to integrate universal design principles into the curriculum and enhance students' understanding and application of these principles.

Virtual reality has also been explored to address specific challenges, such as autism and adaptive skills. The study by Schmidt et al. [5] evaluates a VR intervention designed to teach adaptive skills to adults with autism. The preliminary report highlights the potential of VR in providing immersive and engaging experiences that promote skill development and understanding of individuals with autism.

The literature review by Scavarelli et al. [6] offers a comprehensive overview of the current research on VR and augmented reality (AR) in social learning spaces. It provides insights into using VR and AR technologies for teaching socialisation skills, fostering empathy, and promoting inclusive learning environments.

VIRTUAL REALITY INTERFACES

Virtual reality technology has rapidly evolved in recent years, with numerous companies competing to produce high-quality head-mounted displays (HMDs) that provide immersive experiences [7]. This section explores the landscape of VR hardware and HMDs, highlighting the key players in the industry and their notable contributions. From Google's early foray into VR with Google Cardboard and Google Glass to the luxury VR headsets Varjo offers, the market is diverse and continually evolving. The amount of VR platforms is too numerous to cover fully so this section will only cover a small chunk of the most notable and popular examples.

Commercial head-mounted displays

The HMDs are available from various manufacturers, with distinct features and capabilities. Now, some of the most important HMD products will be covered, organized by manufacturer, enhancing their characteristics, main advantages, and disadvantages.

Google

Google made its mark in the VR HMD world with the introduction of Google Cardboard in 2014. This low-cost, smartphone-based VR platform opened up the possibilities of virtual reality to a wide audience. In the same year, Google unveiled Google Glass, an augmented reality (AR) device. Google focuses on enterprise applications with its Google Glass Enterprise Edition (2017) and Google Glass Enterprise Edition 2 (2019). Additionally, the company has invested in Android AR through ARCore [8–10].

Microsoft

Microsoft gained recognition in the VR industry with the launch of Hololens in 2015. While HoloLens 2 (2019) continues to be utilised in various sectors, such as vehicle manufacturing and design partnerships with companies like Kenworth, Suntory, and Toyota, Microsoft has shown interest in expanding its VR offerings [11–13].

Apple

Apple has recently announced plans to enter the VR market with a premium VR HMD and later, a pair of AR glasses. Although specific details about these devices are scarce, Apple has demonstrated its commitment to VR/AR technologies through patents, such as the ability to convert any surface into a touchscreen. Apple's current presence in the VR market is mainly through its iOS VR/AR support via ARKit [14,15].

Valve

Valve's VR headset, the Valve Index (2019), has been highly regarded for its immersive experience. However, as newer headsets enter the market, the Valve Index is gradually losing popularity. Nonetheless, Valve is known for its exceptional VR controllers. Rumours about releasing a new headset, Valve Index 2 (Project Deckard), are circulating, but no official launch has yet been confirmed [16,17].

Magic Leap

Magic Leap generated significant hype in the VR industry with the release of the Magic Leap One in 2018. The company heavily invested in marketing and VR development; however, their own devices received mixed reviews. The Magic Leap 2 (2022) hasn't gained such a large following community compared to its predecessor. One of their main advantages is the IEC 60601-1 certification that allows its usage on surgical operating rooms [18,19].

HTC

HTC has been a prominent producer of PC-based VR HMDs. Their lineup includes models like the HTC Vive (discontinued), HTC Vive Pro (discontinued), HTC Vive Pro 2, HTC Vive Cosmos, HTC Vive Cosmos Elite, HTC Vive Focus 3 (enterprise only), and HTC Vive Flow. The HTC Vive Pro 2, their latest premium PC headset, delivers a compelling VR experience, while the HTC Vive Flow represents their foray into the standalone HMD market [20,21].

Meta (formerly Oculus)

Originally Oculus before being acquired by Facebook and later rebranded as Meta, the company has released a series of standalone VR hardware. This includes the Oculus Rift CV1 (discontinued), Oculus Go (discontinued), Oculus Rift S (discontinued), Oculus Quest (discontinued), Oculus Quest 2 (renamed to Meta Quest 2), Project Cambria (unreleased), and Quest Pro. The Oculus Meta Quest 2, known for its quality, content variety, and affordability (albeit tied to Facebook connectivity), was the most popular standalone VR HMD for a considerable period. However, Pico has overtaken Quest Pro regarding market share for the newest release among their shared demographic [22–24].

Pico

Pico has emerged as a competitor to Meta (formerly Oculus) in the affordable yet high-quality standalone VR market. Initially primarily focused on the Chinese market due to the absence of Facebook-related restrictions, Pico has expanded its reach. Their lineup includes the Pico G2 4K, Pico G2 4K (China only), Pico Neo 3 Pro (enterprise only), Pico Neo 3 Pro Eye (enterprise only), and Pico 4 + Pico 4 Pro. The latest release, the Pico 4, has gained significant attention and surpassed the popularity of Meta's latest HMD in the Western market [25–27].

HP

HP has made notable strides in the PC VR market with a series of releases. These include the HP Reverb G1, HP Reverb G2 v1, HP Reverb G2 V2, and HP Reverb G2 Omnicept (enterprise only). Collaborating with Valve, HP Reverb G2 V2 is considered one of the top PC VR headsets currently available, offering impressive visual quality and immersive experiences [28,29].

Varjo

Varjo caters exclusively to the luxury side of VR, targeting high-end consumers. Their flagship product, the Varjo Aero, stands out as one of the most expensive luxury VR headsets accessible to the general public. Varjo strongly emphasises providing exceptionally high-resolution displays and premium features to deliver unparalleled virtual reality experiences [30].

Sony

Sony has made its mark in the VR market with 2 headsets designed to work with their PlayStation consoles. The first version, PlayStation VR, quickly became outdated. However, the newer iteration, PlayStation VR 2, specifically caters to the PlayStation console user market, aiming to provide an enhanced and immersive gaming experience [31].

Pimax VR

Pimax VR differentiates itself by prioritising field of view (FoV) and resolution in their VR headsets. They boast some of the highest FoV headsets available, including the Pimax 5K Plus, Pimax Vision 8K Plus, Pimax Vision 5K Super, and Pimax Vision 8KX. Pimax VR's focus on delivering expansive visual experiences has garnered attention from VR enthusiasts seeking the utmost immersion [32,33].

Smartphone AR

In recent years, the advent of smartphone AR and VR has expanded the possibilities of immersive experiences. Smartphones have become a popular platform for AR/VR due to their widespread availability and powerful computational capabilities. Among the key development tools for smartphone AR/VR are ARCore and ARKit, which provide frameworks for creating AR experiences on Android and iOS devices, respectively.

AR Core

ARCore, developed by Google, is an AR platform for Android devices. It offers a range of features, including motion tracking, environmental understanding, and light estimation, allowing developers to create interactive and realistic AR experiences. The ARCore has gained significant traction in the industry and is supported by a wide range of Android devices, making it accessible to a large user base [34].

ARKit

On the other hand, Apple's ARKit is specifically tailored for iOS devices, offering similar capabilities as ARCore. The ARKit provides advanced motion tracking, surface detection, and object recognition, enabling developers to build sophisticated AR applications. With Apple's strong presence in the mobile market, ARKit has gained popularity among developers and users alike [35].

Development tools

To simplify the development process and ensure cross-platform compatibility, tools like ARFoundation, introduced by Unity, have emerged. ARFoundation is a unifying framework that allows developers to create AR experiences compatible with ARKit and ARCore. This significantly reduces the development effort required to target multiple platforms, making it an attractive choice for developers seeking broader reach [36].

In addition to ARCore and ARKit, other tools have surfaced to enhance the creation of AR experiences. Snap Lens Studio, developed by Snapchat, enables users to build AR lenses and filters for Snapchat. It provides an intuitive interface and a wide range of features to create engaging AR content [37].

Another notable tool is Adobe Project Aero, which empowers designers and developers to create immersive AR experiences. Project Aero integrates with popular design tools like Adobe Photoshop and Illustrator, allowing users to transform 2D designs into interactive AR content easily [38].

The rise of smartphone AR/VR platforms has opened unities for developers, designers, and users. With their widespread adoption and continuous technological advancements, smartphone AR/VR platforms, fueled by ARCore and ARKit, offer a powerful and accessible avenue for creating and experiencing immersive augmented and virtual reality applications.

Chosen hardware

The VR hardware and head-mounted display market is a dynamic and competitive landscape, characterised by numerous companies striving to offer the best immersive experiences to consumers. From giants like Google, Microsoft, and Apple to pioneers like Magic Leap and Valve, each company has left its mark on the industry. The HTC, Meta (formerly Oculus), Pico, HP, Varjo, Sony, and Pimax VR have significantly contributed to VR HMDs' evolution, catering to diverse market segments with varying preferences and price ranges. As technology advances, it is exciting to witness the ongoing innovations and improvements in VR hardware, ultimately enhancing users' overall virtual reality experience worldwide.

For authors' purposes, important selection characteristics have been defined as follows:

- the affordable cost, to ensure that an instruction session could simultaneously reach more individuals,
- wireless capabilities, making sure that the use of the HMD does not represent an additional challenge,
- image quality, to ensure the best possible user experience.

Within these requirements, the VR hardware market offered various options from major companies. Among them, the Pico 4 by Pico and the Meta Quest 2 by Meta stand out for their affordability and availability. Their lower price points have made VR more accessible to a broader audience, while their widespread availability streamlined their integration into projects. Regarding general availability, Smartphone AR is more accessible and just as intuitive to develop for small applications, but the platform is too diverse and hardware dependent for more intensive applications.

For the proposed application, the latest Pico headset had not been released by the time development had started, and Meta Quest 2, shown in Figure 1, which was called Oculus Quest 2, was the best available candidate. It is a fully autonomous device with wireless connectivity and features a 1832 × 1920 screen resolution per eye which can run up to 120 Hz of refresh rate. By selecting Meta Quest 2 as the primary platform, excellent software support was also benefited from, along with the advantage of reaching a wider audience owing to its popularity and availability. This decision greatly facilitated the organisation of the activities with the participants, as the headsets eliminated the requirement for additional base stations and the inconvenience of wired connections to a rendering computer. Nevertheless, a challenge was also posed regarding the headset's performance limitations, necessitating meticulous optimization of the graphical rendering pipeline and navigation through the complexities of mesh structures. Despite these obstacles, the accessibility and broad appeal offered by Meta Quest 2 made it the ideal choice for the VR project.

Figure 1. Meta Quest 2, formerly Oculus Quest 2, headset with the included controllers, shown right

VIRTUAL REALITY APPLICATION

To ensure the successful implementation of the project, a rigorous methodology similar to that used in software project development was followed. This methodology was based on 5 distinct planning and requirements gathering, design and architecture, implementation, testing, and operationalisation. The goal for this project is to promote inclusion and foster a more inclusive design approach on a broad scale by allowing users to put themselves "in the shoes of others." To achieve this objective, the functional difficulties experienced by adults and the challenges faced by certain groups whose inherent characteristics may represent exclusion factors were first identified. Through an extensive questionnaire that covered a large population [38], the prevalence of vision and mobility difficulties was identified as significant factors that can create daily challenges. Additionally, the importance of the challenges faced by pregnant women [15], individuals with autism spectrum disorder [10,35], and the elderly [34,35] was recognized. Pregnancy, in particular, is classified as "other impairments" in the World Health Organization International Classification of Impairments, Disabilities, and Handicaps [39] due to the functional limitations that this condition may represent, and it is also mentioned in the International Classification of Functioning, Disability, and Health (ICF) [40]. Individuals with Autism Spectrum Disorder (ASD) can be highly functional, but this neurological and developmental disorder can affect how people interact with others, communicate, learn, and behave. People with autism experience difficulties with social interaction, communication, and imagination. Finally, the elderly can face several difficulties due to mental and physical decline or as a consequence of disease. Despite the large social dimension of these groups, their needs are not always addressed.

Guidelines and requirements

When designing a VR application, it is important to consider the functional requirements that must be met to provide users with an engaging and immersive experience [38,41]. One of the primary requirements is the quality of the hardware. The VR scenario experience must be supported by a HMD capable of rendering high-quality graphics and animations in real-time. This is essential for creating a sense of presence and immersion for the user. The HMD and the running software must also be able to accurately track the user's movements and respond to their actions, minimising any latency or lag in the response time, and optimising the application's performance to prevent motion sickness or other discomforts. In addition to these technical requirements, a VR application must also be designed with engaging and meaningful content for the user. This includes creating a well-designed user interface that is easy to navigate and provides users with clear instructions and feedback. The application must also have a purpose or goal, whether educational, entertaining, or functional, that must be made clear for the user. Additionally, it must be designed to give users a sense of accomplishment or satisfaction upon completion, e.g. using gamification strategies. By addressing these aspects, it is expected that the design of the VR application achieves a careful balance of technical expertise and design sensibility. By prioritising the needs and preferences of the user, the VR experience can be both enjoyable and effective, helping to achieve the desired goals. Furthermore, using game-like elements has benefits in the learning process, such as increased engagement and improved learning outcomes [42]. For these reasons, crucial design elements must be addressed for a successful improvement, such as narrative development, pedagogical alignment, interactivity, and feedback.

Figure 2. Snapshots of the virtual reality environments

The primary objective of the proposed VR application is to facilitate universal design education by conducting interactive sessions, which, in this case, involved a student population. The overarching goal of the application is to enhance users' empathy towards common impairments faced by individuals with disabilities. It is crucial to approach these disabilities with respect for the diversity and uniqueness of disabled individuals.

The application encompasses a range of impairments, including difficulties in independent mobility, various visual impairments, autism, age-related frailty, Alzheimer's disease affecting memory loss, and the physical challenges of advanced pregnancy. The immersive environment demonstrates these impairments to promote a better understanding and empathy towards the experiences of people with disabilities.

Several scenarios were idealized, but for the sake of brevity, the focus will be on the description of 2, each designed to address different aspects of accessibility, inclusion, and functional challenges. The first, as shown in Figure 2, takes place in a supermarket context, which was chosen for its universal relevance to individuals' daily needs (food, hygiene, and others). The application's environment is set within a self-service market, allowing users to engage in shopping tasks. Scenarios and interactions within the application are designed to replicate the shopping experience as closely as possible. By immersing users in this scenario, an experience is aimed to be created that is both relatable and informative, while also being able to cover a wide range of potential impairments and mobility challenges. This scenario offers a diverse set of interaction dynamics, allowing users to navigate the store, select items, and complete various tasks while experiencing the challenges and barriers that individuals with disabilities may face. As an example of a mobility challenge, the need to access areas of the store that are more or less distant or pick up a product that exists on a shelf that is more or less accessible in height can be cited. With a focus on ASD, the possibility of varying light intensity, sound intensity, or the number of people present in different areas of the store, situations that could cause discomfort, can be mentioned. To minimise the need for extensive user instructions, the scenarios and user interface of the VR application are intuitively designed. The choice of a self-service market environment was deliberate, as it is a familiar setting for most potential users. Leveraging users' first-hand knowledge of self-service shopping aims to create a highly intuitive VR application.

The second scenario, as shown in Figure 2, focuses on addressing visual impairments, allowing users to experience firsthand the various difficulties and consequences associated with these conditions. Through this experience, users can explore a range of visual challenges, such as colour blindness, low vision, and visual distortions, in a safe and controlled environment. By providing a virtual experience that simulates real-world conditions, users can gain a deeper understanding of the challenges faced by individuals with visual impairments and develop empathy towards those individuals.

MATERIAL AND METHODS

To realize the VR application, the Unity development environment was employed, which uses the C# programming language. The collaborative nature of the project was facilitated through the use of the GitHub platform, enabling streamlined teamwork and version control.

For logistical, accessibility, and cost reasons, the decision was made to develop the application specifically for the autonomous Meta Quest 2 VR headsets. This choice allowed for the more accessible organisation of student activities, as the headsets eliminated the need for additional base stations and the inconvenience of wired connections to a rendering computer. However, the challenge of dealing with the headset's performance limitations was also presented, necessitating careful optimization of the graphical rendering pipeline and the complexity of mesh structures.

To create the environment for the self-service store, pre-existing assets from the official Unity Asset Store [43] and custom assets created using the free 3D graphics software, Blender [44], were used. Due to the stringent hardware limitations of the target HMDs, mesh structures were thoroughly optimized using specialized tools such as Mesh Simplify by Ultimate Game Tools [45]. This optimisation process ensured optimal performance while maintaining visual fidelity within the constraints of the Meta Quest 2 headsets.

To enhance user interaction, the application was designed to support both controller input and hand-tracking mechanisms. By incorporating commonly used gestures, users were provided with a familiar and intuitive way to navigate the virtual environment. The widely recognised pinch gesture, acting as the trigger button equivalent, was implemented to facilitate interactions within the VR experience.

Logical structure of the developed virtual reality application

The VR application offers 2 distinct modes: unsupervised and supervised. In the unsupervised mode, users can engage in exercise sessions independently, without the application tracking or recording their progress. This mode suits individuals who prefer self-directed workouts or follow specific training routines without external supervision. On the other hand, the supervised mode introduces a structured environment with oversight and interaction between teachers and students during the exercise sessions.

The supervised mode necessitates internet access through a wireless network to establish communication between the HMD and the supervising server. This connection is essential for real-time monitoring and control of exercise progress. Furthermore, exercise organisers, typically the teaching staff, require access to a computer with internet connectivity and a web to operate the HMD application's control panel. The control panel allows them to oversee and guide the exercise sessions effectively.

To ensure seamless and reliable communication between the HMD and the control panel, the developed VR application has been tested using Wi-Fi 6 infrastructure. This next-generation wireless technology provides enhanced speed, capacity, and efficiency, making it an ideal choice for supporting the demands of a VR application. Using less advanced access systems may result in uncontrolled time delays, negatively impacting the overall performance and user experience.

The supervised mode offers several benefits, particularly in educational settings. It facilitates post-exercise discussions between teachers and students, allowing for deeper insights, knowledge consolidation, and meaningful conclusions. Teachers can gauge individual participants' engagement levels through these discussions, providing valuable feedback and personalised guidance. The supervised mode thus enhances the learning experience and enables a more effective evaluation of students' performance.

User interface design

The user interface (UI) of a VR application plays a crucial role in facilitating user interaction and enhancing the overall user experience. This subsection presents the design and implementation of a minimalist and limited UI in the developed VR application. The UI's primary function is to enable users to select parameters and scenarios for their VR experiences, emphasising simplicity and usability. All elements, either graphical [46], music, special effects (FX) [47] or speech [48], must be carefully prepared to maximise user experience. Additionally, the UI incorporates textual shopping lists and the ability to interact with real-world artefacts within a virtual store environment, creating a unique and immersive user experience.

The UI design was an iterative process that involved extensive consultations with focus groups of students, including international participants, during workshops conducted in the form of a summer school. This approach ensured diverse user perspectives and valuable feedback for refining the UI design. The UI was streamlined through multiple iterations to achieve a minimalist aesthetic while maintaining its functionality. The collaborative design process enabled the incorporation of user preferences and considerations, resulting in an interface that meets the needs and expectations of the target user group.

The UI serves as the gateway for users to define their VR experiences. It provides a straightforward selection process for choosing parameters and scenario types. Once the selections are made, the UI transitions into a strongly reduced interface, focusing solely on the necessary information and controls for the chosen scenario. For instance, users engage with a textual shopping list, equipped with auto-checkbox items as they are placed into the virtual shopping cart. This feature enhances user efficiency and reduces the cognitive load during the shopping experience.

Upon successfully fulfilling the shopping mission, users are notified of the task's completion. The UI displays crucial information, including their performance rating, reflecting the level of task execution. This feedback reinforces user engagement and motivation. Furthermore, users are given the choice to continue their interactions within the VR application or conclude their exercises.

To provide a deeper understanding of the challenges faced by individuals with disabilities, the VR experience incorporates selected difficulties that simulate various impairments. This approach allows users to empathise and gain insights into the obstacles faced by people with disabilities in real-life scenarios. Additionally, utilising real-world artefacts within the virtual environment enhances the immersion and authenticity of the experience.

Replicating the struggles of disabilities

The VR application was developed with meticulous attention to detail, ensuring that it imprints distinct impressions of the challenges faced by people with disabilities. By replicating these experiences, sensitization to the realities and hardships encountered by individuals with diverse impairments was sought. The intentional intensification of these experiences accelerates the learning process and fosters empathy among future designers. While the amplified effects may seem exaggerated, their effectiveness in achieving our objectives within a relatively short time frame has been proven. Implementing a supervised learning approach in the VR application allows active teacher intervention throughout the training cycle. Teachers can modulate the intensity of the user's interactions and introduce appropriate modifications to the student's scenario, depending on their specific needs. This dynamic interaction empowers experienced educators to attain additional training outcomes and optimise learning. Consequently, the prepared VR application becomes an elastic and robust educational tool capable of delivering superior results.

The use of VR applications in education, specifically those aimed at replicating the challenges faced by individuals with disabilities, offers significant potential for enhancing learning techniques. By immersing users in these virtual experiences, lasting impressions can be created that sensitize and influence future designers. The deliberate intensification of these experiences accelerates the learning process while incorporating supervised learning enables teachers to shape the training scenarios to meet individual requirements actively. Overall, this carefully designed VR application is a powerful tool for effective and adaptable education.

Simulators

The VR applications are intended to provide visual and auditory stimuli, covering a limited range of the sensory palette. For these reasons, the inclusion of complementary physical accessories and simulators that ensure a more realistic and enriched experience has also been considered. These accessories are carefully designed to facilitate a higher level of engagement and enable users to experience the limitations faced by individuals with disabilities. Some examples of these accessories include wheelchairs, walkers for individuals with impaired mobility, canes and crutches, geriatric suits, pregnancy suit,

a) b) c)

Figure 3. Physical condition simulators (used to enhance the virtual reality user experience): a) pregnancy, b) elderly, c) wheelchair

Parkinson's disease simulation gloves etc. Some of these are shown in Figure 3, where a pregnancy simulator (allowing the perception of the impact on body biodynamics), an elderly simulator (allowing the perception of body rigidity and mobility difficulties), and a wheelchair (allowing the experience of operating the device) can be observed.

By the use of these simulators, high realism in the user experience can be provided. The use of assistive solutions that might be available is minimised to ensure that users encounter the same challenges faced by individuals with disabilities. With these realistic scenarios, the full experience aims to maximise their understanding of the difficulties encountered by people with disabilities. By immersing users in these virtualized experiences, an increase in awareness of the challenges faced by individuals with disabilities is hoped for, inspiring a greater commitment to accessibility and inclusivity in design.

TRAINING METHODOLOGY

To achieve the goal of promoting empathy and understanding, a user-centered pipeline has been created, as depicted in Figure 4, that places the user at the forefront of the VR experience. In this approach, the user is viewed not simply as a passive observer but as an active participant who plays a key role in translating stimuli into a manifestation of empathy.

To evaluate the effectiveness of the proposed methodology, the user's empathy level towards a given context is assessed. For this, a questionnaire oriented to the situation the authors want to work in and to which the user will be exposed has been used. This is a crucial

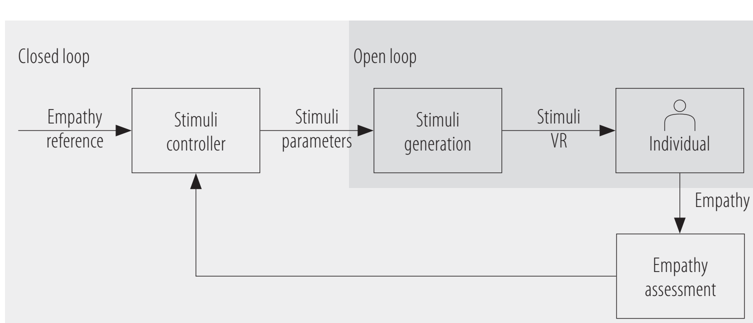

Figure 4. Pipeline for a closed-loop virtual reality experience controller for empathy

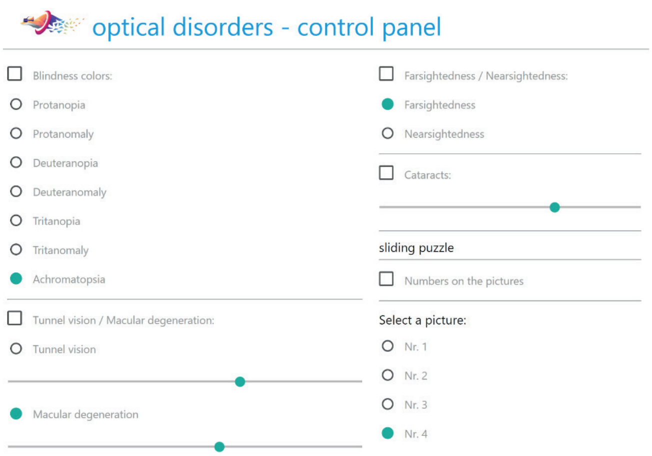

Figure 5. Sight impairment control panel

step because it allows for gaining insight and qualifying or quantifying empathy. The EEG or other physiological signals or biomarkers can be beneficial because it provides an objective value [38], but it was not used in this case. After the empathy assessment, the user is exposed to the stimuli (VR or VR with a physical simulator). In the end, they are subjected again to the same empathy assessment. With this, a closed-loop system is being used, and the empathy gains (difference between the pre- and post-stimuli assessments) can be used to drive further stimuli towards a reference if desired. The user-centered pipeline is designed to be highly adaptable and flexible, allowing for customization based on individual needs and abilities. The sight impairment application has a control panel, as shown in Figure 5, that can manually adjust the type and intensity of the different diseases. But the parameters can also be automatically adjusted according to the user's reactions.

Therefore, by creating a virtual experience that is tailored to the needs and preferences of the user, a deeper connection and understanding between the user and the experience itself is aimed for. By prioritizing the user's input and feedback throughout the design process, the VR experience is ensured to be optimized for maximum impact and effectiveness. Through this approach, a transformative experience is aimed to be created that encourages users to develop greater empathy and understanding for individuals with disabilities and impairments. Users have also been inquired about any discomfort during the use of the HMD or concerning the VR experience. In line with the findings in Hirota et al. [49], most often very positive feedback was received.

CONCLUSIONS

In this article, the potential of utilizing VR applications to increase empathy levels towards individuals with disabilities has been discussed. By going through empathy training, individuals are expected to develop significant motivations and intrinsic greater qualifications towards universal design. The proposed methodologies and presented applications are based on real-world experiences developing such VR experiences.

Throughout the manuscript, detailed insights have been provided into selecting the most suitable HMD set, implementing the application using the Unity programming platform, and the methodology employed for conducting classes using the developed VR application. By employing VR technology, the aim is to bridge the empathy gap and empower students with the skills necessary for inclusive and accessible design. The findings offer valuable guidance for educators and developers interested in leveraging VR for fostering empathy and advancing universal design practices. Overall, the potential of VR applications to augment empathy levels among a student population is showcased. The research outcomes and practical insights presented here contribute to the ongoing exploration of VR's transformative role in promoting inclusivity and empathy in educational settings.

Author contributions
Research concept: Grzegorz Zwoliński, Dorota Kamińska
Research methodology: Grzegorz Zwoliński, Dorota Kamińska
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REFERENCES

1. Watchorn V, Hitch D, Grant C, Tucker R, Aedy K, Ang S, et al. An integrated literature review of the current discourse around universal design in the built environment – is occupation the missing link? Disability and Rehabilitation. 2019 May 17;1–12.
2. Ovienmhada U, Mouftaou F, Wood D. Inclusive Design of Earth Observation Decision Support Systems for Environmental Governance: A Case Study of Lake Nokoué. Frontiers in Climate. 2021 Sep 9;3.

3. Craig SL, Smith SJ, Frey BB. Effects of coaching on Universal Design for Learning implementation. International Journal of Mentoring and Coaching in Education. 2022 Sep 9;
4. Baroni F, Lazzari M. Universal Design for Learning at University: Technologies, Blended Learning and Teaching Methods. 2022 Sep 2;
5. Schmidt M, Schmidt C, Glaser N, Beck D, Lim M, Palmer H. Evaluation of a spherical video-based virtual reality intervention designed to teach adaptive skills for adults with autism: a preliminary report. Interactive Learning Environments. 2019 Feb 13;1–20.
6. Scavarelli A, Arya A, Teather RJ. Virtual reality and augmented reality in social learning spaces: a literature review. Virtual Reality. 2020 May 25;
7. Bury SM, Flower RL, Zulla R, Nicholas DB, Hedley D. Workplace Social Challenges Experienced by Employees on the Autism Spectrum: An International Exploratory Study Examining Employee and Supervisor Perspectives. Journal of Autism and Developmental Disorders. 2020 Aug 18;51(5).
8. Google. Google Cardboard – Google VR [Internet]. Google.com. 2019. Retrieved May 2023. Available from: https://arvr.google.com/cardboard/
9. Google. Glass – Glass [Internet]. Glass. 2019. Retrieved May 2023. Available from: https://www.google.com/glass/start/.
10. Cope R, Remington A. The Strengths and Abilities of Autistic People in the Workplace. Autism in Adulthood. 2021 Oct 7;4(1).
11. Microsoft. Microsoft HoloLens | Mixed Reality Technology for Business [Internet]. Microsoft.com. 2019. Retrieved May 2023. Available from: https://www.microsoft.com/en-us/hololens.
12. Microsoft. HoloLens 2—Pricing and Options | Microsoft HoloLens [Internet]. Microsoft.com. 2019. Retrieved May 2023. Available from: https://www.microsoft.com/en-us/hololens/buy.
13. Editor. Apple Vision Pro: Everything you need to know [Internet]. Macworld. Retrieved May 2023. Available from: https://www.macworld.com/article/557878/apple-reality-headset-ar-vr-design-features-specs-price.html.
14. Patently Apple [Internet]. Patently Apple. Retrieved May 2023. Available from: https://www.patentlyapple.com/patents-granted/.
15. Kazemi F. Disorders Affecting Quality of Life During Pregnancy: A Qualitative Study. Journal Of Clinical And Diagnostic Research. 2017.
16. Headset - Valve Index - Upgrade your experience - Valve Corporation. Headset - Valve Index - Upgrade your experience - Valve Corporation [Internet]. Valvesoftware.com. 2019. Retrieved May 2023. Available from: https://www.valvesoftware.com/en/index/headset.
17. Valve Index 2: Release Date, Features and Cost - VR Expert Blog [Internet]. 2023. Retrieved May 2023. Available from: https://vrx.vr-expert.com/valve-index-2-release-date-features-and-cost-everything-you-need-to-know/.
18. Device [Internet]. www.magicleap.com. [cited 2023 Jun 24]. Retrieved May 2023. Available from: https://www.magicleap.com/magic-leap-1.
19. Device [Internet]. www.magicleap.com. Retrieved May 2023. Available from: https://www.magicleap.com/magic-leap-2.
20. VIVE Cosmos Features | VIVE South East Asia [Internet]. www.vive.com. [cited 2023 Jun 24]. Retrieved May 2023. Available from: https://www.vive.com/sea/product/vive-cosmos/features/.
21. VIVE Focus 3 - VR Headset for Metaverse Solutions | United States [Internet]. www.vive.com. Retrieved May 2023. Available from: https://www.vive.com/us/product/vive-focus3/overview/.
22. Oculus Quest 2: Our Most Advanced All-in-One VR Headset | Oculus [Internet]. www.oculus.com. Retrieved May 2023. Available from: https://www.oculus.com/quest-2/.
23. Project Cambria Hands On: Take a First Look at the Meta Quest Pro VR Headset [Internet]. PCMAG. [cited 2023 Jun 24]. Retrieved May 2023, Available from: https://www.pcmag.com/news/project-cambria-hands-on-take-a-first-look-at-the-meta-quest-pro-vr-headset.
24. Meta Quest Pro: Our Most Advanced New VR Headset | Meta Store [Internet]. www.meta.com. Retrieved May 2023, Available from: https://www.meta.com/quest/quest-pro/.
25. PICO Neo3 Link | Standalone VR Headset | PICO Global [Internet]. www.picoxr.com. Retrieved May 2023, Available from: https://www.picoxr.com/global/products/neo3-link.
26. Live the Game with PICO 4 All-in-One VR Headset | PICO Singapore [Internet]. www.picoxr.com. [cited 2023 Jun 24]. Retrieved May 2023, Available from: https://www.picoxr.com/sg/products/pico4.
27. HP Reverb G2 VR Headset [Internet]. www.hp.com. Retrieved May 2023, Available from: https://www.hp.com/us-en/vr/reverb-g2-vr-headset.html.
28. HP Reverb G2 Omnicept Edition [Internet]. www.hp.com. Retrieved May 2023, Available from: https://www.hp.com/us-en/vr/reverb-g2-vr-headset-omnicept-edition.html.

29. Varjo Aero [Internet]. Varjo.com. Available from: https://varjo.com/products/aero/.
30. PlayStation®VR2 | The next generation of VR gaming on PS5 [Internet]. PlayStation. Available from: https://www.playstation.com/en-us/ps-vr2/.
31. 5K Super | Pimax [Internet]. pimax.com. 2022. Available from: https://pimax.com/pimax-5k-super/.
32. 8K X | Pimax [Internet]. pimax.com. 2022 [cited 2023 Jun 24]. Available from: https://pimax.com/pimax-8k-x/.
33. Technologies U. Unity's AR Foundation Framework | Cross platform augmented reality development software | Unity [Internet]. unity.com. Available from: https://unity.com/unity/features/arfoundation.
34. Nguyen VC, Moon S, Oh E, Hong GRS. Factors Associated With Functional Limitations in Daily Living Among Older Adults in Korea: A Cross-Sectional Study. International Journal of Public Health. 2022 Dec 9;67.
35. Fong JH. Disability incidence and functional decline among older adults with major chronic diseases. BMC Geriatrics. 2019 Nov 21;19(1).
36. Kamińska D, Zwoliński G, Laska-Leśniewicz A. Usability Testing of Virtual Reality Applications—The Pilot Study. Sensors. 2022 Feb 10;22(4):1342.
37. Coelho L, Queiros R, Reis S. Emerging advancements for virtual and augmented reality in healthcare. Hershey, Pa, Usa: Igi Global; 2022.
38. Coelho L, Idalina M.A. Freitas, Dorota Kamińska, Queirós R, Laska-Lesniewicz A, Grzegorz Zwoliński, et al. Virtual and Augmented Reality Awareness Tools for Universal Design. 2022 Jan 1;11–24.
39. Organització Mundial De La Salut. International classification of impairments, disabilities, and handicaps : a manual of classification relating to the consequences of disease. Geneva: World Health Organization; 1993.
40. Peterson DB. International Classification of Functioning, Disability and Health: An Introduction for Rehabilitation Psychologists. Rehabilitation Psychology. 2005;50(2): 105–12.
41. Dorota Kamińska, Grzegorz Zwoliński, Laska-Leśniewicz A, Coelho L. Virtual Reality in Healthcare. 2022 Jan 1; 1–10.
42. Radianti J, Majchrzak TA, Fromm J, Wohlgenannt I. A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. Computers & Education [Internet]. 2020 Apr;147(0360-1315):103778. Available from: https://www.sciencedirect.com/science/article/pii/S0360131519303276.
43. Unity. Unity Asset Store - The Best Assets for Game Making [Internet]. @UnityAssetStore. Unity Asset Store; 2000. Available from: https://assetstore.unity.com/.
44. Blender Foundation. blender.org – Home of the Blender project - Free and Open 3D Creation Software [Internet]. blender.org. 2019. Available from: https://www.blender.org/.
45. Ultimate Game Tools - Asset Store [Internet]. assetstore.unity.com. [cited 2023 Jun 24]. Available from: https://assetstore.unity.com/publishers/1981.
46. Barricelli BR, Gadia D, Rizzi A, Marini DLR. Semiotics of virtual reality as a communication process. Behaviour & Information Technology. 2016 Jul 25;35(11):879–96.
47. Kern AC, Ellermeier W. Audio in VR: Effects of a Soundscape and Movement-Triggered Step Sounds on Presence. Frontiers in Robotics and AI. 2020 Feb 21;7.
48. Coelho L, Braga D, Sales-Dias M, García-Mateo C. An automatic voice pleasantness classification system based on prosodic and acoustic patterns of voice preference. 2011 Aug 27.
49. Hirota M, Kanda H, Endo T, Miyoshi T, Miyagawa S, Hirohara Y, et al. Comparison of visual fatigue caused by head-mounted display for virtual reality and two-dimensional display using objective and subjective evaluation. Ergonomics. 2019 Mar 14;62(6):759–66.
50. VRcompare - The Internet's Largest VR & AR Headset Database. (b. d.). VRcompare. [cited 2023 Jun 24]. Retrieved May 2023. Available from: https://vr-compare.com/.

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