
JMIR XR and Spatial Computing

Volume 1 (2024) ISSN 2818-3045 Editor in Chief: Lars Riedemann, MD

Contents

Viewpoint

- What is Diminished Virtuality? A Directional and Layer-Based Taxonomy for the Reality-Virtuality Continuum
([e52904](#))
Jan Egger, Christina Gsaxner, Jens Kleesiek, Behrus Puladi. 3

Review

- Barriers and Facilitators to the Implementation of Virtual Reality Interventions for People With Chronic
Pain: Scoping Review ([e53129](#))
Alexander Elser, Marina Lange, Christian Kopkow, Axel Schäfer. 11

Editorial

- Discovering and Creating the Leading Edge of Extended Reality and Spatial Computing: A Message From
the Editor-in-Chief ([e64545](#))
Lars Riedemann. 23

Original Papers

- Using Virtual Reality to Reduce Stress in Adolescents: Mixed Methods Usability Study ([e49171](#))
Elin Björling, Jennifer Sonney, Himanshu Zade, Sofia Rodriguez, Michael Pullmann, Soo Moon. 26
- Use of Immersive Virtual Reality in Nursing Homes for People With Dementia: Feasibility Study to Assess
Cognitive, Motor, and Emotional Responses ([e54724](#))
Alexander Prinz, Dan Buerger, Jelena Krafft, Matteo Bergmann, Alexander Woll, Bettina Barisch-Fritz, Kerstin Witte. 41
- Immediate Impact of an 8-Week Virtual Reality Educational Program on Burnout and Work Engagement
Among Health Care Professionals: Pre-Post Pilot Study ([e55678](#))
Jose Ferrer Costa, Nuria Moran, Carlos Garcia Marti, Leomar Colmenares Hernandez, Florin Radu Ciorba Ciorba, Maria Ciudad. 53
- Perspectives of Medical Students and Developers Regarding Virtual Reality, Augmented Reality, Mixed
Reality, and 3D Printing Technologies: Survey Study ([e54230](#))
Young Yun, Dong Shin, Hyung Choi. 67

Brain Activation During Virtual Reality Symptom Provocation in Obsessive-Compulsive Disorder: Proof-of-Concept Study (e47468)	
Martine van Bennekom, Guido van Wingen, Willem Bruin, Judy Luigjes, Damiaan Denys.	89
Virtual Reality for Basic Life Support Training in High School Students: Thematic Analysis of Focus Group Interviews (e53212)	
Hyojin Min, Caroline Andler, Rebecca Barber, Todd Chang, Cristian Abelairas-Gomez, Laquanda Knowlin, Deborah Liu, Nino Fija ko.	99
Factors Associated With Risky Drinking Decisions in a Virtual Reality Alcohol Prevention Simulation: Structural Equation Model (e56188)	
Robert Hrynyschyn, Julie Guldager, Daniel Schulze, Patricia Lyk, Gunver Majgaard, Christiane Stock.	107
Exploring How Virtual Reality Could Be Used to Treat Eating Disorders: Qualitative Study of People With Eating Disorders and Clinicians Who Treat Them (e47382)	
Helen Bould, Mari-Rose Kennedy, Ian Penton-Voak, Lisa Thomas, Jon Bird, Lucy Biddle.	121
Enhancement of Immersive Technology Use in Pediatric Health Care With Accessible, Context-Specific Training: Descriptive Feasibility Study (e56447)	
Brian Li, Brendan Fereday, Ellen Wang, Samuel Rodriguez, Karin Forssell, André Bollaert, Maria Menendez, Thomas Caruso.	136
Mobile Phone–Based Personalized and Interactive Augmented Reality Pictorial Health Warnings for Enhancing a Brief Advice Model for Smoking Cessation: Pilot Randomized Controlled Trial (e52893)	
Ziqiu Guo, Yongda Wu, Man Wang.	145
Assessing Predictive Factors of Attitudes Toward Peer-Supported Mental Health Interventions in the Metaverse: Mixed Methods Study (e57990)	
Francisco Ramos, Rachel Bernstein, Iony Ezawa.	157
Experience of Youths and Older People With Virtual Reality Games for Cognitive Assessment: Inductive Thematic Analysis and Insights for Key Stakeholders (e59197)	
Yesoda Bhargava, Veeky Baths.	170

Viewpoint

What is Diminished Virtuality? A Directional and Layer-Based Taxonomy for the Reality-Virtuality Continuum

Jan Egger^{1,2,3}, PhD; Christina Gsaxner^{1,4,5}, PhD; Jens Kleesiek^{3,6,7}, MD, PhD; Behrus Puladi^{4,5}, MD, DMD

¹Institute of Computer Graphics and Vision, Graz University of Technology, Graz, Austria

²Center for Virtual and Extended Reality in Medicine, Essen University Hospital, Essen, Germany

³Institute for Artificial Intelligence in Medicine, Essen University Hospital, Essen, Germany

⁴Department of Oral and Maxillofacial Surgery, University Hospital RWTH Aachen, Aachen, Germany

⁵Institute of Medical Informatics, University Hospital RWTH Aachen, Aachen, Germany

⁶Partner Site Essen, German Cancer Consortium, Essen, Germany

⁷Department of Physics, TU Dortmund University, Dortmund, Germany

Corresponding Author:

Jan Egger, PhD

Institute of Computer Graphics and Vision

Graz University of Technology

Inffeldgasse 16c/2

Graz, 8010

Austria

Phone: 43 316 873 5076

Email: egger@icg.tugraz.at

Abstract

The concept of reality-virtuality (RV) continuum was introduced by Paul Milgram and Fumio Kishino in 1994. It describes a spectrum that ranges from a purely physical reality (the real world) to a purely virtual reality (a completely computer-generated environment), with various degrees of mixed reality in between. This continuum is “realized” by different types of displays to encompass different levels of immersion and interaction, allowing for the classification of different types of environments and experiences. What is often overlooked in this concept is the act of diminishing real objects (or persons, animals, etc) from the reality, that is, a diminution, rather than augmenting it, that is, an augmentation. Hence, we want to propose in this contribution an update or modification of the RV continuum where the diminished reality aspect is more prominent. We hope this will help users, especially those who are new to the field, to get a better understanding of the entire extended reality (XR) topic, as well as assist in the decision-making for hardware (devices) and software or algorithms that are needed for new diminished reality applications. However, we also propose another, more sophisticated directional and layer-based taxonomy for the RV continuum that we believe goes beyond the mediated and multimeditated realities. Furthermore, we initiate the question of whether the RV continuum truly ends on one side with physical reality.

(*JMIR XR Spatial Comput* 2024;1:e52904) doi:[10.2196/52904](https://doi.org/10.2196/52904)

KEYWORDS

reality-virtuality continuum; diminished virtuality; Apple Vision Pro; VR; virtual reality; reality-virtuality; mixed reality; augmented reality; XR; extended reality; taxonomy; classification; classifications; concept; concepts; conceptual

Introduction

The reality-virtuality (RV) continuum is a concept introduced by Paul Milgram and Fumio Kishino [1] in 1994. It describes a spectrum that ranges from a purely physical reality (the real world) to a purely virtual reality (VR; a completely computer-generated environment), with various degrees of mixed reality (MR) in between. This continuum is “realized” by different types of displays [2] to encompass different levels

of immersion and interaction, allowing for the classification of different types of environments and experiences. The RV continuum helps us understand the varying levels of immersion and interactivity that technology can provide. As technology advances, the boundaries between these immersion levels can become more fluid, and new hybrid experiences can emerge. The continuum is particularly relevant in fields such as VR, augmented reality (AR), and MR, where researchers and developers aim to create more compelling and natural

experiences that bridge the gap between the physical and virtual worlds. We used ChatGPT (OpenAI) [3] to gauge the current state of the RV continuum. According to ChatGPT, the continuum is often divided into several main categories (note,

we adapted the ChatGPT results and enhanced it with concrete examples, where necessary; [Textbox 1](#) [4]). The original ChatGPT transcript is shown in [Multimedia Appendix 1](#) [3].

Textbox 1. Main categories of the reality-virtuality continuum, modified from ChatGPT.

ChatGPT prompt:

- What is the reality-virtuality continuum?

Main categories (modified ChatGPT output):

- Physical reality (real environment): This is the state of the unmediated physical world, where all sensory perceptions are naturally experienced without any technological augmentation.
- Augmented reality (AR): In this category, virtual elements are overlaid onto the real world. AR enhances the user's perception of the physical world by adding computer-generated visual, auditory, or haptic information. Examples include smartphone apps that display digital information on top of real-world views, such as Pokémon GO [5].
- Mixed reality (MR): MR environments combine virtual and physical elements in a way that allows them to interact in real time. Users can manipulate both virtual and real objects, and the distinction between the 2 can be blurred. Microsoft's HoloLens is an example of an MR device that enables users to interact with holographic objects in their real-world environment [6].
- Virtual reality (VR): In VR, users are completely immersed in a computer-generated environment that can simulate various sensory experiences. VR typically involves the use of head-mounted displays and other input devices to provide a sense of presence within the virtual environment [7]. Prominent examples are the HTC Vive and the Meta Quest.
- Augmented virtuality (AV): This term is less commonly used than the others. It refers to scenarios where real-world elements are brought into a virtual environment. For example, capturing real objects or people and placing them into a virtual space. The Varjo XR-3 is capable of providing such a function and is able to make a video stream into the virtual world (VR). A concrete example could be showing a video stream of the (real) smartphone in VR, so the user can answer a text message without actually leaving VR (removing the headset and thus breaking the illusion being in "another world," the simulated virtual environment).

Diminished Reality

What is often overlooked in this concept is the act of *diminishing* real objects (or persons, animals, etc) from reality, rather than *augmenting* the reality with virtual things [8,9]. An introduction to the topic can be found in Cheng et al [10]. A reason for this is that diminishing something from reality needs, in general, a sophisticated understanding of the real scene or environment to make the *diminishing* aspect convincing. In AR, the real world is *just* overwritten with a virtual object. In diminished reality (DR), however, the real-world part that is *augmented* or *diminished* needs to seemingly *fit* to the reality around it. In addition, this should all be performed in real time when a user is walking around the real world, and an algorithm has to do the following (note that the first 3 items are part of the Extent of World Knowledge axis of the taxonomy by Milgram and Kishino [1]):

- Detect and track the real object that has to be removed or diminished;
- Perform geometric modeling of the scene and objects to be added or subtracted (preexisting or captured once or in real time);
- Apply the lighting model of the scene to objects added or to part of the revealed scene when something is removed (preexisting or captured once or in real time); and then
- Combine all the previous points together as the scene description for the rendering algorithm.

All of this has to be done not only in real time but also with very high precision. The inserted virtual object has to fit seamlessly into and make sense with the reality; minor

discrepancies will appear to be a glitch and will be noticed immediately by the user, as we recently observed in a DR user study [11]. In fact, we think that diminution and augmentation require fundamentally different technologies. In our opinion, an augmentation may be needed to alter reality at a certain position with regard to other (real) objects (eg, displaying a patient's tumor as an AR hologram on the patient in front of you, at the real position, such as for needle guidance [12]), but no seamless and semantic fitting is necessary. As soon as a virtual object needs to fit into the scene semantically, we consider this to require diminution. Hence, for augmentation, you *only* need a volume rendering process with some basic options, such as position, size, and transparency. For diminution, however, additional fundamentally different technologies are needed. The scene has to be analyzed and *understood*, and a meaningful replacement has to be generated and *inserted* as an AR hologram. An example could be glasses that are *removed* from a person in front of you.

In summary, the user has to get the impression that the real, diminished object does not exist at all in reality [13]. Besides sophisticated algorithms, this course of action needs a considerable amount of computing power. Fortunately, there has been tremendous progress in both areas during the last years, with deep learning-based approaches and GPUs that can run these kinds of algorithms, even in real time. As a result, DR has already found its way into some applications [5], such as virtual furniture removal for redecorating purposes (eg, IKEA Kreativ [14]). Other possible applications for DR include the following:

- Privacy enhancing: In a live video feed, certain objects or information can be blurred or removed in real time to protect sensitive or private data.
- Training and education: DR can be used to remove distractions in a learning environment or highlight specific items to focus on.
- Therapeutic applications: For someone with a phobia of spiders, a DR system could recognize spiders in the person's field of view and diminish or replace them with less threatening images to reduce anxiety. Additionally, sensory overload, a feature of autism, could be diminished with a DR system, to reduce overstimulation.

Directional and Layer-Based Taxonomy

Nevertheless, for all these aforementioned reasons, we think that DR needs to be more prominent on the RV continuum, as shown in [Figure 1 \[15\]](#), without delving deeper into the broad topics of mediated reality [9] or even multimediated reality [16]. This will not only assist in the decision-making for hardware (devices) and software that are needed for new DR applications but also help unfamiliar users to get a better understanding of the entire extended reality (XR) topic (note that we are addressing this revision to the continuum purely from an application or user point of view [POV], not from the POV of an MR researcher or engineer). An example application for DR could be the real-time anonymization of a face via XR. There is a huge difference if a device detects the eye area and *simply*

inpaints a black bar over the eyes (without considering the surrounding facial area) or inpaints the eyes with *different* or *meaningful* ones that fit perfectly to the surrounding facial area. The black bar approach can probably be performed on a current smartphone, whereas the second approach needs much more sophisticated hardware and computing power, with an integrated GPU that can run a trained, deep inpainting neural network in real time (note that a user with an XR headset would move around in general, which also changes the POV on the face to be anonymized, so the inpainting algorithms also has to be executed continuously in real time). In this context, we also think that the upcoming Apple Vision Pro will push the limits in DR, because it is a video-see-through device that can enable DR to reach its full potential [17]. In fact, the *Digital Crown* hardware of the Apple Vision Pro, which also exists for the Apple Watch, should enable us to seamlessly *walk* along the whole RV continuum (back and forth) and bring medical DR applications to reality, which are still almost nonexistent currently [18]. A potential example of the photo-editing capabilities of newer cell phones as a diminution operation is shown in [Figure 2 \[15\]](#). In this medical example, DR enables the *removal* of a skin tumor virtually from a patient's face before surgery.

Diminished virtuality (DV), however, remains a curiosity, and not even ChatGPT—which has been fed with 300 billion words from books, web texts, Wikipedia, articles, etc [4]—can handle this term as of January 2024 ([Textbox 2](#); the original ChatGPT transcript is shown in [Multimedia Appendix 2 \[3\]](#)).

Figure 1. An updated reality-virtuality continuum where “diminishing” is more prominent to ensure a better understanding. The figure shows a real operation room (OR), which is “real” in the two left columns and computer-generated in the two right columns. In “reality,” a real physician is standing inside an OR without any computer-generated objects. In “augmented reality,” the real physician wears extended reality (XR) glasses in the OR and looks at a computer-generated skull of the patient to be treated. In “augmented-diminished reality,” the real OR table has been removed (but also note that the computer-generated skull is not visualized). On the right side is “virtuality,” that is, virtual reality (VR), where a computer-generated OR with a table and a skull are shown in VR (to a user wearing VR glasses). In “augmented virtuality,” the real physician is shown inside the VR OR. In “augmented-diminished virtuality” (ie, mediated virtuality), the computer-generated OR table is removed, but note that the real physician is still shown. In “diminished virtuality,” the OR table has been removed, but the real physician is also not shown. The “augmenting-diminishing” continuum shows the degree of augmentation and diminution (note that this does not apply for “reality” and “virtuality”). Scenarios where a diminution happens belong to “disrupted reality.” The images within the figure were generated by DALL-E 3 (OpenAI) [15] and then further modified by the authors.

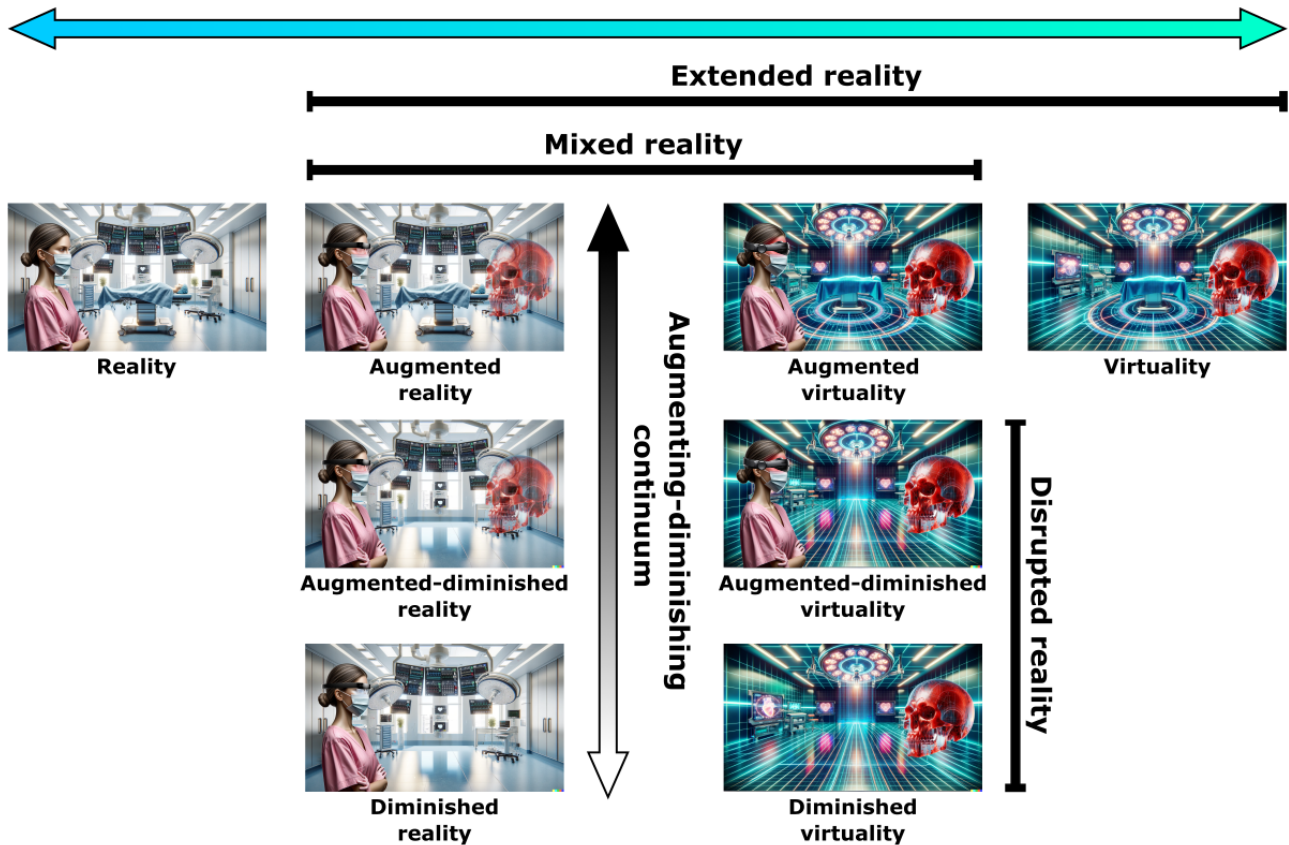


Figure 2. An example of the photo-editing capabilities of newer cell phones as a diminution operation, enabling the “removal” of a skin tumor virtually from a patient’s face before surgery. This figure was generated by DALL-E 3 (OpenAI) [15] and then further modified by the authors.



Textbox 2. Asking ChatGPT about “Diminished Virtuality” (as of January 2024).

ChatGPT prompt:

- What is “Diminished Virtuality”?

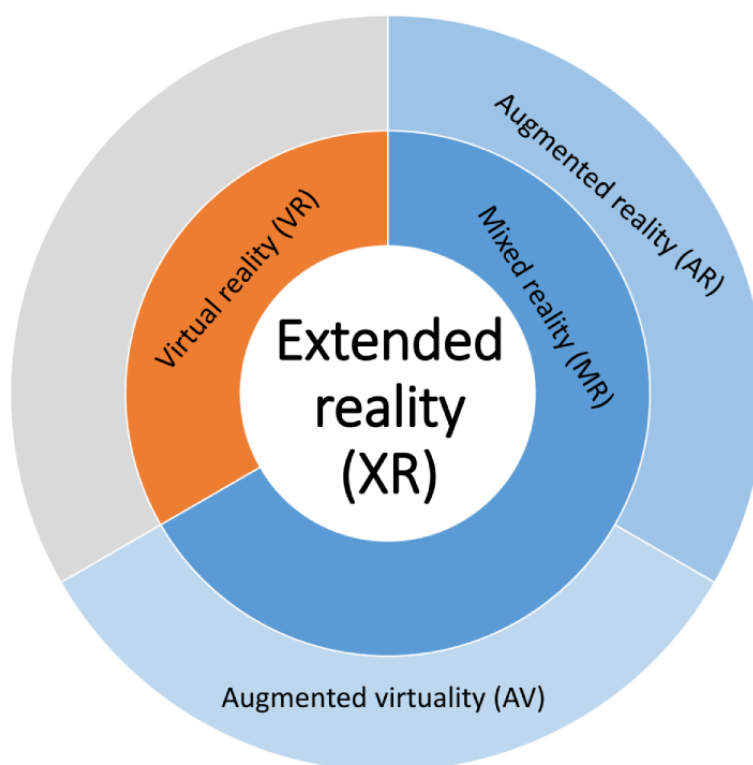
ChatGPT output:

- “Diminished Virtuality” is not a widely recognized term or concept as of my last knowledge update in January 2022. It’s possible that this term has been coined or introduced in a specific context or field after that date, or it may be a term used in a niche or specialized area that is not widely known.
- If you have more context or information about where you came across this term or its usage, I would be happy to try to provide more information or insight based on that context.

DV can perhaps be best imagined as starting on the extreme right side on the RV continuum, which contains only virtual objects (virtual environment and VR), and going along the continuum toward the left to reach diminished virtual elements (see the figure of the RV continuum by Iriqat and Vatansever [19], and note that this is especially of interest for computer-generated structures that are very complex and where only some parts need to be diminished). This should be possible with the *Digital Crown* hardware of the Apple Vision Pro: when fully immersed, the virtuality is reduced to make the real world partly visible. Apple describes scenarios where people might want to increase the pass-through when they intend to interact with a nearby physical object or read text on another device. Another real-world scenario could be a so-called tumor board meeting that is held in VR, where several experts from around the world gather to discuss a rare case and certain virtual elements (images, texts, etc) are diminished because of privacy issues (note that the mixture of reality here is also modifiable): an externally tuned-in expert (who is traveling) can see certain patient information because he or she belongs to the clinic where the patient is located, whereas another externally tuned-in expert who does not belong to the clinic of the patient should not see or hear certain patient information. However, the full potential of DV would unfold when the virtuality is diminished in a way that also fits with the upcoming reality. An example would be a real-world person showing up in VR between virtual objects. Imagine layers of virtual and real context stacked up but still seamlessly interplay with each other for the final output. In fact,

this layer-based concept could also extend to mediated and even multimeditated realities, where, for example, different sounds (real and virtual) interplay with each other, depending on their location and *depth*. “Enaudio” (the “hearing” equivalent to envision) hearing real rain outside in the real world that are mixed with virtual sounds while inside a virtual room. Real and virtual input from different senses could also be mixed; for example, there is a (virtual) hole in the VR room and the (real) rain falls inside this virtual room, generating simulated sounds as they hit virtual objects in the VR room. The same also works for outputs and their combinations; for example, the real voice from someone wearing the headset is mixed with virtual sounds, or real smells are mixed into VR by generating the corresponding virtual objects there. Finally, some could argue whether the RV continuum really ends on *one side* with physical reality [20], because the brain creates reality—comparable to a head-mounted display creating VR—but does not detect it. This could be discussed and explored by the community in the future, and in this regard, we want to propose a diagram of XR that loops back (as opposed to a continuum on a straight line with 2 ends) as an inspiration (Figure 3). In summary, XR is a niche yet growing topic, because more and more consumer devices with better hardware have become available during the last few years. In parallel, artificial intelligence (AI)-based algorithms have made 1 breakthrough after another, which can, for example, be explored to develop novel applications for an intelligent health care metaverse [21].

Figure 3. The extended reality (XR) continuum with its subsections (virtual reality [VR], mixed reality [MR], augmented reality [AR], and augmented virtuality [AV]) folded in an outside-in fashion with a circular representation.



Acknowledgments

This work was supported by TU Graz Open Access Publishing Fund. BP was funded by the Medical Faculty of the RWTH Aachen University in Germany as part of the Clinician Scientist Program. CG was funded by the Advanced Research Opportunities Program (AROP) from the RWTH Aachen University. Furthermore, we acknowledge the Center for Virtual and Extended Reality in Medicine (*Zentrum für virtuelle und erweiterte Realität in der Medizin*; ZvRM [22]) of the University Hospital in Essen, Germany. We used the generative AI tool ChatGPT by OpenAI to identify the main categories of the reality-virtuality continuum and the status of diminished virtuality, which were further review and revised by the study group. The original ChatGPT transcripts are made available as [Multimedia Appendices 1](#) and [2](#). Parts of [Figures 1](#) and [2](#) were created using the generative AI tool DALL·E 3 by OpenAI [15].

Conflicts of Interest

BP is an associate editor of the *Journal of Medical Internet Research*. The other authors have no conflicts of interest to declare.

Multimedia Appendix 1

Asking ChatGPT about "the reality-virtuality continuum."

[[PNG File , 303 KB - xr_v1i1e52904_app1.png](#)]

Multimedia Appendix 2

Asking ChatGPT about "diminished virtuality."

[[PNG File , 212 KB - xr_v1i1e52904_app2.png](#)]

References

1. Milgram P, Kishino F. A taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems* 1994 Dec;E77-D(12):1321-1329 [[FREE Full text](#)]
2. Milgram P, Takemura H, Utsumi A, Kishino F. Augmented reality: a class of displays on the reality-virtuality continuum. In: *SPIE Proceedings, Volume 2351, Telemicroscopy and Telepresence Technologies*. 1995 Dec 21 Presented at: Photonics for Industrial Applications 1994; October 31 to November 4, 1994; Boston, MA p. 282-292. [doi: [10.1117/12.197321](https://doi.org/10.1117/12.197321)]
3. ChatGPT. OpenAI. URL: <https://chat.openai.com/> [accessed 2024-01-23]

4. Kim JK, Chua M, Rickard M, Lorenzo A. ChatGPT and large language model (LLM) chatbots: the current state of acceptability and a proposal for guidelines on utilization in academic medicine. *J Pediatr Urol* 2023 Oct;19(5):598-604. [doi: [10.1016/j.jpuro.2023.05.018](https://doi.org/10.1016/j.jpuro.2023.05.018)] [Medline: [37328321](https://pubmed.ncbi.nlm.nih.gov/37328321/)]
5. Lawler-Sagarin KA, Sagarin BJ, Pederson A. Enhanced community through augmented reality: social benefits of Pokémon Go. *Psychol Rep* 2023 Aug 22;332941231197155. [doi: [10.1177/00332941231197155](https://doi.org/10.1177/00332941231197155)] [Medline: [37605801](https://pubmed.ncbi.nlm.nih.gov/37605801/)]
6. Gsaxner C, Li J, Pepe A, Jin Y, Kleesiek J, Schmalstieg D, et al. The HoloLens in medicine: a systematic review and taxonomy. *Med Image Anal* 2023 Apr;85:102757 [FREE Full text] [doi: [10.1016/j.media.2023.102757](https://doi.org/10.1016/j.media.2023.102757)] [Medline: [36706637](https://pubmed.ncbi.nlm.nih.gov/36706637/)]
7. Gruber LJ, Egger J, Bönsch A, Kraeima J, Ulbrich M, van den Bosch V, et al. Accuracy and precision of mandible segmentation and its clinical implications: virtual reality, desktop screen and artificial intelligence. *Expert Syst Appl* 2024 Apr;239:122275. [doi: [10.1016/j.eswa.2023.122275](https://doi.org/10.1016/j.eswa.2023.122275)]
8. Mori S, Ikeda S, Saito H. A survey of diminished reality: techniques for visually concealing, eliminating, and seeing through real objects. *IPSJ Transactions on Computer Vision and Applications* 2017 Jun 28;9:17. [doi: [10.1186/s41074-017-0028-1](https://doi.org/10.1186/s41074-017-0028-1)]
9. Mann S. Mediated reality with implementations for everyday life. *Presence Connect* 2002 Aug 6 [FREE Full text]
10. Cheng YF, Yin H, Yan Y, Gugenheimer J, Lindlbauer D. Towards understanding diminished reality. 2022 Apr Presented at: CHI '22: CHI Conference on Human Factors in Computing Systems; April 29 to May 5, 2022; New Orleans, LA p. 1-16. [doi: [10.1145/3491102.3517452](https://doi.org/10.1145/3491102.3517452)]
11. Gsaxner C, Mori S, Schmalstieg D, Egger J, Paar G, Bailer W, et al. DeepDR: deep structure-aware RGB-D inpainting for diminished reality. *arXiv Preprint* posted online on December 1, 2023. [doi: [10.48550/arXiv.2312.00532](https://doi.org/10.48550/arXiv.2312.00532)]
12. Gsaxner C, Li J, Pepe A, Schmalstieg D, Egger J. Inside-out instrument tracking for surgical navigation in augmented reality. 2021 Dec Presented at: VRST '21: 27th ACM Symposium on Virtual Reality Software and Technology; December 8-10, 2021; Osaka, Japan p. 1-11. [doi: [10.1145/3489849.3489863](https://doi.org/10.1145/3489849.3489863)]
13. Schmidt S. Blended spaces: perception and interaction in projection-based spatial augmented reality environments [dissertation]. University of Hamburg. 2020. URL: <https://ediss.sub.uni-hamburg.de/bitstream/ediss/8644/1/dissertation.pdf> [accessed 2024-01-22]
14. Liang YW, Huang YH. Exploration of user experience in mixed reality for product virtual interaction and display. 2023 Presented at: 2023 IEEE 6th International Conference on Knowledge Innovation and Invention (ICKII); August 11-13, 2023; Sapporo, Japan p. 404-409. [doi: [10.1109/ICKII58656.2023.10332563](https://doi.org/10.1109/ICKII58656.2023.10332563)]
15. DALL-E 3. OpenAI. URL: <https://openai.com/dall-e-3> [accessed 2024-01-25]
16. Mann S, Furness T, Yuan Y, Iorio J, Wang Z. All reality: virtual, augmented, mixed (X), mediated (X,Y), and multimediated reality. *arXiv Preprint* posted online on April 20, 2018. [doi: [10.48550/arXiv.1804.08386](https://doi.org/10.48550/arXiv.1804.08386)]
17. Egger J, Gsaxner C, Chen X, Bian J, Kleesiek J, Puladi B. Apple Vision Pro for healthcare: "the ultimate display"? - entering the wonderland of precision medicine. *arXiv Preprint* posted online on August 8, 2023. [doi: [10.48550/arXiv.2308.04313](https://doi.org/10.48550/arXiv.2308.04313)]
18. Ienaga N, Bork F, Meerits S, Mori S, Fallavollita P, Navab N, et al. First deployment of diminished reality for anatomy education. 2016 Presented at: 2016 IEEE International Symposium on Mixed and Augmented Reality (ISMAR-Adjunct); September 19-23, 2016; Merida, Mexico p. 294-296. [doi: [10.1109/ismar-adjunct.2016.0099](https://doi.org/10.1109/ismar-adjunct.2016.0099)]
19. Iriqat S, Vatansever F. Comparison of reality types. *Uludağ University Journal of The Faculty of Engineering* 2020 Dec 31;25(3):1155-1168. [doi: [10.17482/uumfd.789985](https://doi.org/10.17482/uumfd.789985)]
20. Hutzler F. Reverse inference is not a fallacy per se: cognitive processes can be inferred from functional imaging data. *Neuroimage* 2014 Jan 1;84:1061-1069 [FREE Full text] [doi: [10.1016/j.neuroimage.2012.12.075](https://doi.org/10.1016/j.neuroimage.2012.12.075)] [Medline: [23313571](https://pubmed.ncbi.nlm.nih.gov/23313571/)]
21. Wang G, Badal A, Jia X, Maltz JS, Mueller K, Myers KJ, et al. Development of metaverse for intelligent healthcare. *Nat Mach Intell* 2022 Nov;4(11):922-929. [doi: [10.1038/s42256-022-00549-6](https://doi.org/10.1038/s42256-022-00549-6)] [Medline: [36935774](https://pubmed.ncbi.nlm.nih.gov/36935774/)]
22. Zentrum für virtuelle und erweiterte Realität in der Medizin. Universitätsklinikum Essen. URL: <https://zvr.ume.de/> [accessed 2023-01-23]

Abbreviations

- AI:** artificial intelligence
- AR:** augmented reality
- AV:** augmented virtuality
- DR:** diminished reality
- DV:** diminished virtuality
- MR:** mixed reality
- POV:** point of view
- RV:** reality-virtuality
- VR:** virtual reality
- XR:** extended reality

Edited by T Leung; submitted 19.09.23; peer-reviewed by M Hirota, K Sharrad; comments to author 24.10.23; revised version received 14.11.23; accepted 26.12.23; published 31.01.24.

Please cite as:

Egger J, Gsaxner C, Kleesiek J, Puladi B

What is Diminished Virtuality? A Directional and Layer-Based Taxonomy for the Reality-Virtuality Continuum

JMIR XR Spatial Comput 2024;1:e52904

URL: <https://xr.jmir.org/2024/1/e52904>

doi: [10.2196/52904](https://doi.org/10.2196/52904)

PMID:

©Jan Egger, Christina Gsaxner, Jens Kleesiek, Behrus Puladi. Originally published in JMIR XR and Spatial Computing (<https://xr.jmir.org>), 31.01.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR XR and Spatial Computing, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Review

Barriers and Facilitators to the Implementation of Virtual Reality Interventions for People With Chronic Pain: Scoping Review

Alexander Elser¹, MSc; Marina Lange¹, MSc; Christian Kopkow², Prof Dr; Axel Georg Schäfer¹, Prof Dr

¹Faculty of Social Work and Health, HAWK Hildesheim/Holzminden/Göttingen University of Applied Sciences and Arts, Hildesheim, Germany

²Department Therapy Science I, Faculty 4 for Human Sciences, Brandenburg University of Technology Cottbus – Senftenberg, Senftenberg, Germany

Corresponding Author:

Alexander Elser, MSc

Faculty of Social Work and Health

HAWK Hildesheim/Holzminden/Göttingen University of Applied Sciences and Arts

Goschentor 1

Hildesheim

Germany

Phone: 49 5121881121

Email: alexander.elser@hawk.de

Abstract

Background: Chronic pain is a growing health problem worldwide with a significant impact on individuals and societies. In regard to treatment, there is a gap between guideline recommendations and common practice in health care, especially concerning cognitive and psychological interventions. Virtual reality (VR) may provide a way to improve this situation. A growing body of evidence indicates that VR therapy has positive effects on pain and physical function. However, there is limited knowledge about barriers and facilitators to the implementation of VR interventions for people with chronic pain in health care settings.

Objective: The aim of this study was to identify and analyze the barriers and facilitators involved in implementing VR interventions for people with chronic pain.

Methods: We conducted a scoping review of the German and English literature using the MEDLINE, Cochrane Central Register of Controlled Trials, CINAHL, PEDro, LILACS, and Web of Science (inception to November 2023) databases, including quantitative, qualitative, and mixed methods studies reporting barriers and facilitators to the implementation of VR interventions for people with chronic pain, as reported by patients or health care professionals. Two reviewers systematically screened the abstracts and full texts of retrieved articles according to the inclusion criteria. All mentioned barriers and facilitators were extracted and categorized according to the Theoretical Domains Framework (TDF).

Results: The database search resulted in 1864 records after removal of duplicates. From the 14 included studies, 30 barriers and 33 facilitators from the patient perspective and 2 facilitators from the health care professional perspective were extracted. Barriers reported by people with chronic pain were most frequently assigned to the TDF domains environmental context (60%) and skills (16.7%). Most facilitators were found in three domains for both the patients and health care professionals: beliefs about consequences (30.3%), emotions (18.2%), and environmental context (18.2%).

Conclusions: The findings of this review can inform the development of strategies for future implementations of VR interventions for people with chronic pain. Additionally, further research should address knowledge gaps about the perspective of health care professionals regarding the implementation of VR interventions for people with chronic pain.

(*JMIR XR Spatial Comput* 2024;1:e53129) doi:[10.2196/53129](https://doi.org/10.2196/53129)

KEYWORDS

virtual reality; VR; chronic pain; implementation science; scoping review; barriers; facilitators

Introduction

Chronic pain is defined as persistent or recurrent pain lasting longer than 3 months [1]. Chronic pain is an increasingly prevalent health condition worldwide, as three of the primary

contributors to years lost to disability in recent decades are chronic pain conditions (back pain, musculoskeletal disorders, and neck pain) [2,3]. Estimated pooled prevalence rates for chronic pain in adults vary across studies from 20.5% in the United States [4] to 28.3% in Germany [5], 34% in the United

Kingdom [6], and 48.1% in Chile [7]. High prevalence of chronic pain is not only found in industrial nations but also in low- and middle-income countries, where the prevalence ranges from 13% to 49.4% [8]. Chronic pain affects not only adults but also has a significant prevalence in children, adolescents, and young adults, ranging from 8% to 23% [8-10]. Common consequences of chronic pain include physical disability, psychological distress, and reduced quality of life [3,11]. Furthermore, chronic pain affects relationships and self-esteem and is associated with higher rates of divorce and suicide [12,13]. From a societal perspective, chronic pain places an enormous financial burden on health care systems. In Australia, the financial costs associated with chronic pain were estimated to be ~US \$57.1 billion in 2018 [14]. In the United States, the Institute of Medicine estimated that the annual cost of chronic pain, including medical costs and lost productivity, was US \$560 billion to US \$635 billion in 2010 [15]. In Germany, chronic pain was estimated to cost at least US \$63.7 billion annually [16]. At the same time, the care situation for people with chronic pain is characterized by a shortage of health care specialists, resulting in an inadequate supply of treatments [17], particularly of psychotherapy [18]. In contrast, the guidelines for chronic pain explicitly recommend interdisciplinary multimodal pain management, including cognitive and psychological interventions [19].

Virtual reality (VR) is a relatively new nonpharmacological modality to help people suffering from chronic pain, which can also help to improve the care situation [20]. VR treatment for people with chronic pain includes VR games, mindfulness-based interventions, practical exercises, and visual illusions [21]. A meta-analysis showed large effects of VR interventions on pain (standardized mean difference [SMD] 1.6, 95% CI 0.83-2.36) and body functioning (SMD 1.4, 95% CI 0.13-2.67) in people with chronic pain [21]. Although the mechanisms underlying the observed benefits of VR for chronic pain are not yet fully understood, distraction of the patient and embodiment have been discussed as possible explanations for changes in outcomes [20]. Distraction is based on the limited capacity of people to simultaneously attend to different stimuli [22]. It is assumed that attention that would normally be focused on pain is redirected to the VR experience, thereby reducing or eliminating the perception of pain [23]. Embodiment describes the experience of the virtual body in virtual space and can lead to a change in the perception of the physical body and the body matrix, which can have a positive effect on pain perception and physical activity in people with chronic pain [24]. Other mechanisms, including the gamification of exposure to feared movements through the VR [25] and accelerated time perception in VR [26], have also been proposed to have an influence on chronic pain.

VR can therefore be seen as a promising therapeutic option for people with chronic pain. However, there has been no large-scale implementation of this technology in the health care of people with chronic pain. Previous research has shown that organizational structures and the VR technology itself are barriers to the implementation of VR interventions in various health care settings [27-29]. Regarding the use of VR in physiotherapy, due to technical limitations, lack of protocols

for VR interventions, and patient-related factors, VR itself seems to be the main barrier [30]. Conversely, staff and health care professionals may act as facilitators, as they reduce the anxiety of new technologies and can change patients' attitudes toward VR. Health care professionals are also generally interested in using VR in rehabilitation [28-30]. However, people with chronic pain are a group with unique characteristics and diverse impairments, as they may experience pain-related fears and fear of movement, and often have maladaptive coping strategies, mental disorders such as depression or anxiety [31], or cognitive impairments [32]. Since these factors may influence the implementation of VR interventions, it is essential to identify barriers and facilitators for this population in using VR to derive a targeted implementation strategy.

A systematic implementation strategy is necessary to enable large-scale successful implementation and use of VR interventions for people with chronic pain. This requires a comprehensive review of all known barriers and facilitators. The Theoretical Domains Framework (TDF) offers an approach to systematically examine barriers and facilitators toward the development of an implementation strategy [33]. The TDF is an implementation framework for behavioral change that incorporates 128 theoretical concepts derived from 33 different behavior change theories and organizes them into 14 domains into which the barriers and facilitators can be classified [33]. The findings gained in this way can be used to support implementation efforts. For example, this approach was used to support the implementation of stratified care for people with nonspecific low back pain in Canada [34], and was also used to inform the development and implementation of digital tools in a bariatric surgery service [35].

Therefore, the aim of this scoping review was to systematically identify and categorize barriers and facilitators to the implementation of VR interventions for people with chronic pain. The identified barriers and facilitators will provide a basis for recommendations for the successful integration of VR interventions into clinical practice, future development of VR interventions, and future implementation studies in the field of chronic pain management.

Methods

Study Design and Registration

A scoping review was conducted to comprehensively search and synthesize the published literature on barriers and facilitators reported by patients and health care professionals in implementing VR interventions for the treatment of people with chronic pain. The methodological background for this scoping review is based on the five steps outlined by Arksey and O'Malley [36] and the methodological guidance for conducting scoping reviews published by the Joanna Briggs Institute [37]. Reporting follows the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) guidelines; the PRISMA-ScR checklist can be found in [Multimedia Appendix 1](#) [38]. The scoping review was registered with the Open Science Framework [39].

Search Strategy, Eligibility Criteria, and Selection of Evidence Sources

A database-specific literature search was conducted in the electronic databases MEDLINE (through PubMed), Cochrane Central Register of Controlled Trials, CINAHL, PEDro, LILACS, and Web of Science on November 1, 2022. A search strategy was developed using the keywords “chronic pain,” “virtual reality,” and “implementation.” The detailed search string for each database can be found in [Multimedia Appendix 2](#). Additionally, one reviewer (AE) screened the reference lists of the included studies.

The search results were combined and uploaded to CADIMA, a web application that assists in conducting and documenting the evidence synthesis process [40], which we used for the selection process. After removing duplicates, two authors (AE and ML) independently screened the titles and abstracts of identified publications.

The initial inclusion criteria for publications were: (1) use of quantitative, qualitative, or mixed method study designs; (2) involves people with any type of chronic pain; (3) the treatment was a VR intervention; (4) published in the English or German language; and (5) reported implementation outcomes. The exclusion criterion was studies involving children (aged <18 years).

Two reviewers (AE and ML) tested the inclusion and exclusion criteria by screening the titles and abstracts of a random sample of 25 publications to ensure consistent use. If agreement was below 75%, the criteria were adjusted [41]. After title and abstract screening, the reviewers (AE and ML) discussed refining the criteria for full-text screening. As a result, the criterion to include only studies that specifically reported barriers or facilitators as reported by patients or health care professionals as implementation outcomes was added. Barriers were defined as any factors that inhibit or negatively influence patients’ use of a VR intervention. Facilitators were defined as all factors that enhance or positively influence patients’ use of a VR intervention. Barriers and facilitators had to be self-reported by patients or health care professionals. The two reviewers (AE and ML) independently screened the full texts. Disagreements throughout the review process were resolved by discussion between the two reviewers.

Data Charting Process

One reviewer (AE) extracted the data into a custom data template created for the purpose of this scoping review (see

[Multimedia Appendix 3](#)). A second reviewer (ML) reviewed all extracted data and commented on discrepancies, which were resolved through discussion. We extracted study characteristics (title, authors, year of publication, design, population, and sample size), intervention characteristics (setting, type of intervention), and barriers and facilitators (separately for patients and health care professionals). From qualitative studies, all barriers and facilitators reported by patients or health care professionals were extracted. For quantitative studies, barriers and facilitators were extracted if $\geq 50\%$ of participants agreed that this factor had an influence on the implementation of VR interventions [42].

Collating, Summarizing, and Reporting

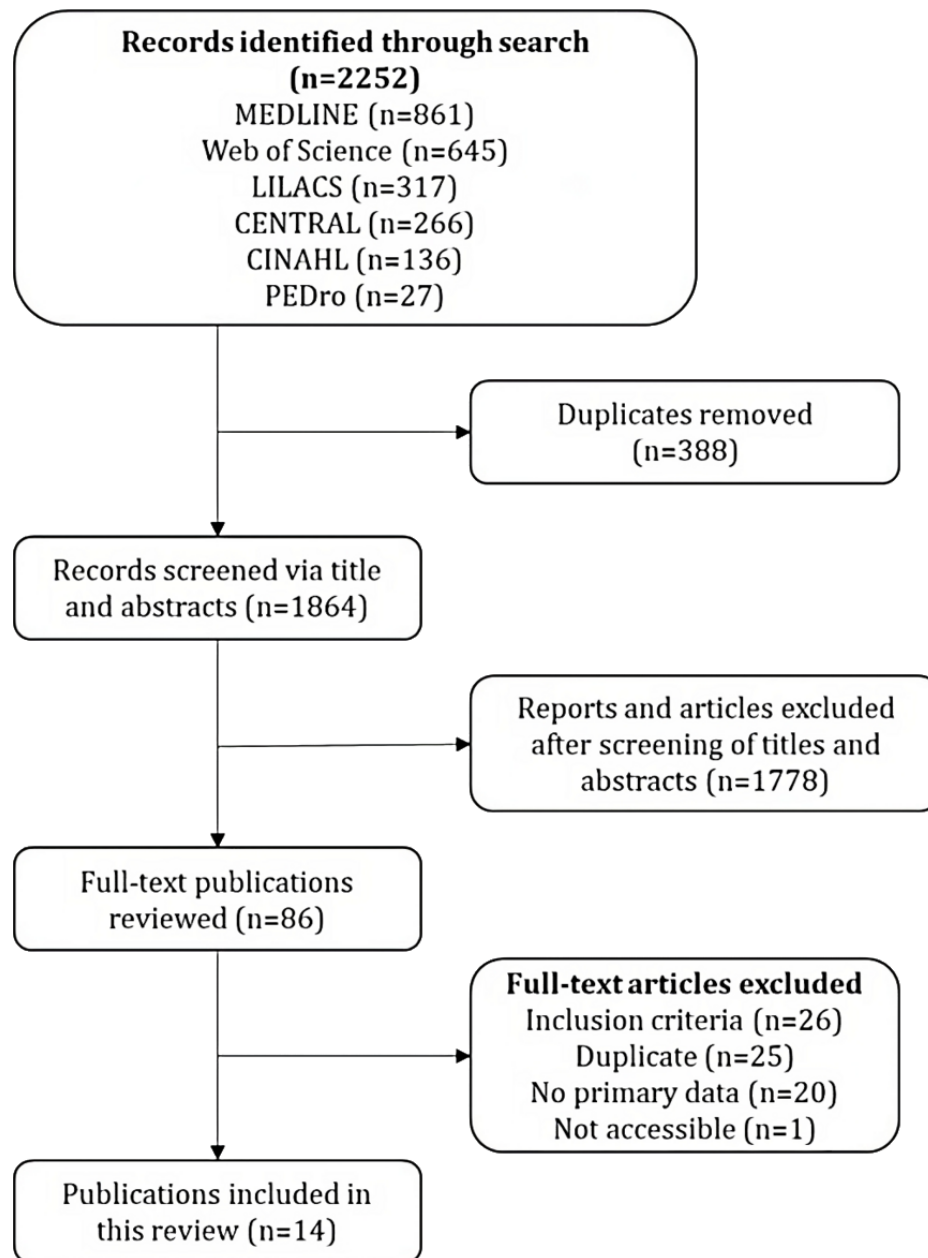
The resulting data were transferred into MAXQDA Plus 2022 (VERBI software, 2021) to code and categorize the barriers and facilitators separately for patients and health care professionals according to the domains of the TDF (see [Multimedia Appendix 4](#)). After coding of the barriers and facilitators by two reviewers (AE and ML), inconsistencies were resolved through discussion. Extracted barriers and facilitators could be categorized in more than one domain.

After evaluation of the number of barriers and facilitators assigned to each domain of the TDF, separately for patients and health care professionals, the most common barriers and facilitators were analyzed to determine underlying themes.

Results

Study Selection

The database search resulted in 2252 publications. After removal of 388 duplicates, 1864 titles and abstracts were screened. Of those, 86 publications met the inclusion and exclusion criteria and were subject to screening of the full text. Among these 86 publications, 72 were excluded because they did not meet the inclusion criteria, were duplicates, did not provide primary data, or were not accessible. Duplicates occurred again in the screening of full texts because the initial removal of duplicates before the screening of titles and abstracts was based solely on the DOI. However, some publications were not recognized by CADIMA in this step due to missing DOIs. Finally, 14 studies were included in the qualitative analysis. The entire selection process is shown in the PRISMA-ScR flowchart in [Figure 1](#).

Figure 1. Flowchart of search and screening results.

Description of Included Studies

Of the 14 studies, there were 8 mixed methods studies [43-50], four qualitative studies [51-54], and two quantitative studies [55,56]. All studies reported barriers and facilitators from the patient perspective, whereas one study also reported barriers and facilitators from the health care professional perspective [53]. The included studies were published between 2013 and 2022, with 9 studies published in 2020 or later [43-46,51-53,55,56]. The sample size of the studies ranged from 7 [49] to 84 [50] participants, with the mean age ranging from 35.86 [49] to 81.85 [55] years. The studies included various VR interventions such as a 5-minute nature relaxation video [46], physically active tasks [43], and specifically developed interventions with guided exercises for focused attention and open awareness [50]. For more information on the

characteristics, study settings, and VR interventions of the included studies, please refer to [Multimedia Appendix 5](#) [43-56].

Overview of Identified Barriers and Facilitators

A total of 65 barriers and facilitators were identified. Among these, there were 30 (46%) barriers and 33 (51%) facilitators from the patient perspective and 2 (3%) facilitators reported from the health care professional perspective. All identified barriers and facilitators are summarized for each TDF domain in [Multimedia Appendix 6](#).

Barriers From the Patient Perspective

The 30 barriers identified from the patient perspective were categorized into six different TDF domains ([Table 1](#)). The other eight TDF domains did not address the barriers identified from the patient perspective.

Table 1. Barriers and facilitators from the patient perspective assigned to Theoretical Domains Framework (TDF) domains.

TDF domains	Barriers (n=30), n (%)	Facilitators (n=33), n (%)
Environmental context and resources	18 (60)	6 (18)
Skills	5 (17)	1 (3)
Memory, attention, and decision processes	2 (7)	0 (0)
Emotion	2 (7)	6 (18)
Beliefs about consequences	1 (3)	10 (30)
Reinforcement	0 (0)	4 (12)
Knowledge	0 (0)	2 (6)
Behavioral regulation	0 (0)	2 (6)
Optimism	0 (0)	1 (3)
Beliefs about capabilities	0 (0)	1 (3)

One of the two most important domains was the *environmental context and resources* (ECR) domain, which included the most barriers from the patient perspective. Three main themes emerged (Table 2). The first was related to the VR devices themselves, with barriers such as the devices being too heavy, too expensive, not detecting all movements, and problems when people with chronic pain were wearing glasses. Furthermore, insufficient support during implementation was perceived as a barrier. The second theme was that the VR software made people with chronic pain feel sick or caused more pain. In addition,

the tutorial of the software was considered to be too difficult. Finally, notable events included technical problems, problems with use due to physical impairments, and patients being in too much pain to use.

Within the domain *skills*, we identified two main barrier-related themes: (1) gaming skills, as the software was too difficult to use and patients without previous experience in playing video games had difficulties controlling the game; and (2) other skills, in which the main barrier was language if the patient's first language was not the same language as that used in the software.

Table 2. Main barrier-related themes from the patient perspective according to Theoretical Domains Framework domains.

Themes	Quote/description	References
Environmental context and resources		
VR ^a devices	"A negative factor was that the VR glasses were heavy to wear"	Glavare et al [45]
VR software	"Yeah, that would really have to be under guidance, yeah. [...] So they [peers] wouldn't be able to do it alone"	Stamm et al [52]
Notable events	"I've got really bad arthritis too at the moment so holding onto those [hand controls] was an issue"	Kelly et al [51]
Skills		
Gaming skills	"I had some trouble figuring out which controls to use to move around so um I've never played computer games before and maybe that had something to do with it. I felt like a total idiot totally frustrated and not able to catch onto what to do"	Garrett et al [48]
Other skills	The exceptions were those whose first language was not English and who described difficulties in understanding game instructions	Tuck et al [43]

^aVR: virtual reality.

Facilitators From the Patient Perspective

The 33 facilitators were assigned to nine different domains of the TDF (Table 1). No facilitators were assigned to the other five domains of the TDF.

The most frequently identified facilitators were categorized in the domain *beliefs about consequences*. A closer look at this domain revealed the following three main themes: (1) positive expectations in regard to therapy effects, (2) the VR interventions are helpful for rehabilitation, and (3) the VR

interventions support doing therapy regularly (Table 3). Among the positive expectations for treatment effects, pain, feelings of anxiety and depression, as well as expectations that VR interventions are superior to conventional therapy were mentioned as facilitators. VR interventions were reported to be helpful for rehabilitation because they improved the mood, well-being, and concentration of people with chronic pain. Similarly, people with chronic pain stated that using VR interventions would increase their adherence with the health behavior and that they would use it on a regular basis.

Table 3. Main facilitator-related themes from the patient perspective according to Theoretical Domain Framework domains.

Themes	Quote/description	Reference
Beliefs about consequences		
Positive expectations	“I had really high hopes...I thought it might actually take my pain away”	Tuck et al [43]
Helpful for rehabilitation	“I’ve taken opiates for 40 years and they don’t work as well as what the virtual reality did”	Kelly et al [51]
Increase adherence	“Especially in the future, you could have thousands of different situations that you could immerse yourself in, for as much time as you want in the day”	Garrett et al [53]
Environmental context and resources		
VR ^a devices	Several participants noted that flexibility in the position of use and brevity of time in the experience had helped manage or entirely avoid such discomfort: “I’m not in as much pain when I’m seated as when I’m standing, so it was quite easy for me to do the movements”	Kelly et al [51]
Supervising therapist	“I think it makes you feel better that it’s a trained physiotherapist. You knew they had that background and it just fills you with confidence a bit more”	Tuck et al [43]
Gamification	“Positive factors were that VR added a dimension of playfulness and gaming to the exercise”	Galavare et al [45]
Emotion		
Fun and enjoyment	The competition against the computer opponents increased engagement and several participants mentioned the feeling of satisfaction they got when they performed well	Mortensen et al [54]
Novel and unknown experiences	“you’re enjoying yourself, you can do things you’ve never experienced before, obviously you’re going to do it”	Kelly et al [51]

^aVR: virtual reality.

One of the second most frequently identified facilitators was ECR, with three main themes: (1) VR devices, (2) a supervising therapist, and (3) gamification. The VR devices serve as a facilitator because they are simple to use for people with chronic pain, easily adjustable, and can be used in different positions. Similarly, a supervising therapist is considered to facilitate the implementation of a VR intervention. The gamification of therapy through VR interventions was also perceived as a facilitating factor by people with chronic pain.

The second most frequently identified facilitator was classified under the *emotion* domain of the TDF. Within this domain, two main themes were derived: (1) fun and enjoyment, in which people with chronic pain reported that VR interventions triggered positive emotions and evoked a high level of satisfaction; and (2) novel and unknown experiences that the people with chronic pain are not able to experience in the real world.

Facilitators From the Health Care Professional Perspective

Only two facilitators from the health care professional perspective were identified, which were assigned to the domains *ECR* and *beliefs about consequences*. Health care professionals indicated that the opportunity to be with the patient during the VR intervention and to be able to intervene in adverse events supports its implementation. Another facilitating factor from the health care professional perspective was that the VR

intervention allows patients to practice everyday situations in therapy, such as working in the garden.

Discussion

Overview

The aim of this scoping review was to identify and categorize barriers and facilitators associated with the implementation of VR interventions for people with chronic pain, using the TDF. From the 14 included studies [43-56], a total of 65 barriers and facilitators from the patient perspective and two facilitators from the health care professional perspective were identified. The main barriers from the patient perspective to use VR interventions for chronic pain were assigned to the domains *environmental context and resources* and *skills*. However, the domains *ECR*, *beliefs about consequences*, and *emotions* also included facilitators that increased the use of VR interventions from a patient perspective. Health care professional perspectives are poorly researched, with only one study [52] found on this topic. To our knowledge, this is the first scoping review summarizing barriers and facilitators to the implementation of VR interventions for people with chronic pain.

Selection of a VR Device

At first glance, a contradictory result of this study is that the *ECR* domain includes barriers as well as facilitators to the implementation of VR interventions for chronic pain. However, since VR devices and VR software emerged as major themes within the barriers and facilitators in this domain, an important

step in implementing VR interventions appears to be the selection of an appropriate VR device and VR software for patients with chronic pain and in consideration of their actual conditions. This decision may be particularly important for people with chronic neck pain, as they may be more sensitive to the weight of VR devices, which could lead to an increase in pain [49]. Although future technological developments of VR devices with lower weight might improve this limitation, the use of VR devices for people with chronic neck pain will remain an individual decision depending on individual tolerance. If these steps are taken carefully, it is possible that the chosen VR device and the VR intervention itself will act as a facilitator in the implementation process. These findings support three proposed aspects to be considered when preparing a VR therapy: the right VR intervention at the right time and with the right patient [57]. These findings are consistent with published recommendations to adopt a participatory approach involving the patients themselves throughout the development process of VR interventions to consider all of the above aspects at an early stage [58].

VR Skills

A second important TDF domain including barriers was *skills*, relating specifically to the patient's gaming skills and language skills. Both can be addressed in software development, such as by participatory developed tutorials or using plain language. These recommendations are partly reflected in the recommendations for the participatory development of VR interventions [58] and are also in line with a previous review, which argued for providing sufficient time to learn and use the new technology for patients and health care professionals [27]. However, our findings emphasize the importance of developing and providing plain-language options in VR interventions for people with chronic pain, potentially due to their shorter attention spans and greater susceptibility to interruption [59], as well as other mental health concerns such as psychological distress [11], anxiety, and depression [31]. For existing interventions, these barriers can be addressed with an implementation strategy. As part of such a strategy, special attention should be given to competencies of health care professionals related to the use of VR to enable them to teach the acquired skills to their patients with individual needs [29]. Additionally, for a successful implementation, it is important that health care professionals are positive about the digital technology [60] and perceive it as user-friendly [61]. Thus, a key aspect of implementing VR in the treatment of chronic pain is adequate training of the health care professionals who will provide the VR interventions to people with chronic pain.

No barriers in regard to game design quality, such as poor graphics or boring games, were reported by people with chronic pain or health care professionals, which was a somewhat surprising finding. Considering the publication dates of the literature retrieved and our own experience with VR interventions, it would have been conceivable that the grade of immersion or perceived difference between the virtual world and the real world could still be experienced as a barrier to using VR interventions.

VR Treatment Expectations

Existing positive expectations regarding pain improvement and rehabilitation facilitate the implementation of VR interventions for people with chronic pain [43,51,53,55,56]. A positive belief in VR interventions seems to result in more satisfaction with the outcome of therapy in general [30] and has an impact on cooperation and outcomes in people with chronic pain in general [62]. When implementing VR interventions for people with chronic pain, this positive belief can be used and facilitated by educating patients about the positive effects of the intervention and presenting best-practice examples.

Another theme that emerged within the domain beliefs about consequences is that VR interventions could increase treatment adherence because VR helps people with chronic pain to improve health behaviors and their ability to focus on tasks [56]. In addition, patients see the possibility that in the future they will be able to choose from many different virtual scenarios in which they can immerse themselves to help with their pain [53].

Lack of patient adherence is a common problem associated with poorer treatment outcomes [63,64] and VR may be a viable option to reduce this problem. Our results are in line with a previous review, which showed that VR can encourage patients to adhere to treatment [30]. VR and its potential impact on adherence may facilitate high-intensity therapy and thereby improve outcomes, as a network meta-analysis showed that high-intensity therapy in particular can have a positive impact on outcomes in chronic pain therapy [65].

The themes fun and enjoyment and having novel experiences provide an explanation for the above-mentioned good adherence to VR interventions. The ability of VR to provide novel experiences for people with chronic pain has also been highlighted in other studies [30]. Furthermore, positive emotions such as fun and enjoyment may themselves have a positive impact, considering that negative emotions are a risk factor for the development and maintenance of chronic pain [66].

Perspective of the Health Care Professionals

In our scoping review, we were only able to identify one study that focused on facilitators from the perspective of health care professionals, who naturally play a crucial role in the implementation of digital interventions [60]. Health care professionals mentioned that VR is a good opportunity to treat people with chronic pain in everyday situations and that they want to be close to the patients during the treatment [53].

Integration With Existing Literature

When comparing the findings of this review with findings from other reviews looking at the implementation of VR interventions in various health care settings [29], rehabilitation [27], and physical therapy [30], it is notable that the identified themes differ only in terms of the details and cover mostly similar topics such as the barrier of appropriate VR interventions and VR devices for the individual patient, as well as the facilitators of having a strong belief in the efficacy of these interventions. This preliminary finding suggests that implementing VR interventions for people with chronic pain is not fundamentally different from implementation in other settings; however, due

to the nature of chronic pain, cognitive and functional impairments should be taken into account. Additionally, since the health care professional perspective is not fully understood, further research on this aspect is necessary.

Limitations

One limitation of this scoping review is that classification of barriers and facilitators into TDF domains may be subjective, although we aimed to minimize subjectivity by standardized procedures using a coding guideline based on TDF domains with two independent reviewers. In this scoping review, barriers and facilitators were ranked according to how often they were mentioned in the included studies. However, this may not necessarily reflect their importance. Barriers and facilitators mentioned only once may nevertheless be the most important factor in a particular implementation setting. In particular, barriers and facilitators in quantitative studies were included if they had more than 50% agreement in the study, whereas all barriers and facilitators mentioned in qualitative studies were included. This may impact the distribution of barriers and facilitators.

The review process did not include a critical appraisal of the studies; although this is not standard practice for scoping reviews, it might be considered a limitation regarding the quality of the evidence. Furthermore, only studies published in German

or English were included. This may limit conclusions about implementation in other countries.

Recommendations

Our findings provide a comprehensive overview of the barriers and facilitators to implementing VR interventions for people with chronic pain in the existing literature. Based on the identified barriers, the development of VR devices and VR interventions should address the perspectives of both people with chronic pain and health care professionals. This could reduce language, cognitive, or physical barriers that are important for patients with specific impairments.

Based on the identified barriers and facilitators, systematic and targeted implementation strategies for VR interventions for people with chronic pain can be developed. For example, the barrier of lack of skills can be reduced by offering targeted training to health care professionals, and positive expectations of VR interventions can be reinforced, such as by displaying a poster about the positive effects of VR in the waiting room. In addition, future research on VR interventions and implementation should pay more attention to the perspective of health care professionals to gain better insight into the values and needs of these critical stakeholders. This can be achieved through an implementation study that includes a formative evaluation of the implementation steps with a focus on health care professionals and their experiences in the process.

Acknowledgments

This study is part of the “Zukunft FH-PROF” project at the HAWK University of Applied Sciences and Arts and was supported by the “FH Personal” funding program of the Federal Ministry of Education and Research and the State of Lower Saxony (funding code 03FHP179).

Data Availability

The data sets generated and analyzed during this study are available from the corresponding author on reasonable request.

Authors' Contributions

AE, AGS, and CK contributed to conceptualization. AE developed the search strategy and conducted the search. AE and ML screened titles and abstracts and the full text, extracted the data, and categorized the data into domains. AE summarized the domains. AE wrote the original draft; manuscript review and editing were performed by all authors (most notably AGS and CK).

Conflicts of Interest

None declared.

Multimedia Appendix 1

PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) checklist. [[DOCX File, 46 KB - xr_v1i1e53129_app1.docx](#)]

Multimedia Appendix 2

Search strategy.

[[DOCX File, 15 KB - xr_v1i1e53129_app2.docx](#)]

Multimedia Appendix 3

Data extraction sheet.

[[XLSX File \(Microsoft Excel File\), 11 KB - xr_v1i1e53129_app3.xlsx](#)]

Multimedia Appendix 4

Description of domains in the Theoretical Domains Framework.

[\[PDF File \(Adobe PDF File\), 83 KB - xr_v1i1e53129_app4.pdf \]](#)

Multimedia Appendix 5

Description of the included studies.

[\[DOCX File, 23 KB - xr_v1i1e53129_app5.docx \]](#)

Multimedia Appendix 6

Summary of all identified barriers and facilitators according to Thematic Domains Framework domains.

[\[XLSX File \(Microsoft Excel File\), 11 KB - xr_v1i1e53129_app6.xlsx \]](#)**References**

1. Treede R, Rief W, Barke A, Aziz Q, Bennett MI, Benoliel R, et al. A classification of chronic pain for ICD-11. *Pain* 2015 Jun;156(6):1003-1007. [doi: [10.1097/j.pain.000000000000160](https://doi.org/10.1097/j.pain.000000000000160)] [Medline: [25844555](https://pubmed.ncbi.nlm.nih.gov/25844555/)]
2. Murray CJL, Atkinson C, Bhalla K, Birbeck G, Burstein R, Chou D, Foreman, Lopez, Murray, Dahodwala, Jarlais, Fahami, Murray, Jarlais, U.S. Burden of Disease Collaborators. The state of US health, 1990-2010: burden of diseases, injuries, and risk factors. *JAMA* 2013 Aug 14;310(6):591-608. [doi: [10.1001/jama.2013.13805](https://doi.org/10.1001/jama.2013.13805)] [Medline: [23842577](https://pubmed.ncbi.nlm.nih.gov/23842577/)]
3. GBD 2016 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2017 Sep 16;390(10100):1211-1259. [doi: [10.1016/S0140-6736\(17\)32154-2](https://doi.org/10.1016/S0140-6736(17)32154-2)] [Medline: [28919117](https://pubmed.ncbi.nlm.nih.gov/28919117/)]
4. Yong RJ, Mullins PM, Bhattacharyya N. Prevalence of chronic pain among adults in the United States. *Pain* 2022 Feb 01;163(2):e328-e332. [doi: [10.1097/j.pain.0000000000002291](https://doi.org/10.1097/j.pain.0000000000002291)] [Medline: [33990113](https://pubmed.ncbi.nlm.nih.gov/33990113/)]
5. Häuser W, Schmutzer G, Hilbert A, Brähler E, Henningsen P. Prevalence of chronic disabling noncancer pain and associated demographic and medical variables: a cross-sectional survey in the general German population. *Clin J Pain* 2015 Oct;31(10):886-892. [doi: [10.1097/AJP.000000000000173](https://doi.org/10.1097/AJP.000000000000173)] [Medline: [25411861](https://pubmed.ncbi.nlm.nih.gov/25411861/)]
6. Fayaz A, Croft P, Langford RM, Donaldson LJ, Jones GT. Prevalence of chronic pain in the UK: a systematic review and meta-analysis of population studies. *BMJ Open* 2016 Jun 20;6(6):e010364. [doi: [10.1136/bmjopen-2015-010364](https://doi.org/10.1136/bmjopen-2015-010364)] [Medline: [27324708](https://pubmed.ncbi.nlm.nih.gov/27324708/)]
7. Durán J, Tejos-Bravo M, Cid V, Ferreccio C, Calvo M. Chronic pain in Chile: first prevalence report of noncancer chronic pain, fibromyalgia, and neuropathic pain and its associated factors. *Pain* 2023 Aug 01;164(8):1852-1859. [doi: [10.1097/j.pain.0000000000002886](https://doi.org/10.1097/j.pain.0000000000002886)] [Medline: [36893316](https://pubmed.ncbi.nlm.nih.gov/36893316/)]
8. Jackson T, Thomas S, Stabile V, Shotwell M, Han X, McQueen K. A systematic review and meta-analysis of the global burden of chronic pain without clear etiology in low- and middle-income countries: trends in heterogeneous data and a proposal for new assessment methods. *Anesth Analg* 2016 Sep;123(3):739-748. [doi: [10.1213/ANE.0000000000001389](https://doi.org/10.1213/ANE.0000000000001389)] [Medline: [27537761](https://pubmed.ncbi.nlm.nih.gov/27537761/)]
9. Liao ZW, Le C, Kynes JM, Niconchuk JA, Pinto E, Laferriere HE, et al. Paediatric chronic pain prevalence in low- and middle-income countries: a systematic review and meta-analysis. *EClinicalMedicine* 2022 Mar;45:101296. [doi: [10.1016/j.eclinm.2022.101296](https://doi.org/10.1016/j.eclinm.2022.101296)] [Medline: [35198925](https://pubmed.ncbi.nlm.nih.gov/35198925/)]
10. Farrant B, Denny S, Vroegop P, Fenaughty J, Clark TC. Prevalence, severity and impact of chronic pain among a representative cross-sectional study of New Zealand high school students. *J Paediatr Child Health* 2023 Jan;59(1):144-152. [doi: [10.1111/jpc.16263](https://doi.org/10.1111/jpc.16263)] [Medline: [36334005](https://pubmed.ncbi.nlm.nih.gov/36334005/)]
11. Du S, Hu Y, Bai Y, Hu L, Dong J, Jin S, et al. Emotional distress correlates among patients with chronic nonspecific low back pain: a hierarchical linear regression analysis. *Pain Pract* 2019 Jun;19(5):510-521. [doi: [10.1111/papr.12772](https://doi.org/10.1111/papr.12772)] [Medline: [30739397](https://pubmed.ncbi.nlm.nih.gov/30739397/)]
12. Suso-Ribera C, Yakobov E, Carriere JS, García-Palacios A. The impact of chronic pain on patients and spouses: consequences on occupational status, distribution of household chores and care-giving burden. *Eur J Pain* 2020 Oct;24(9):1730-1740. [doi: [10.1002/ejp.1616](https://doi.org/10.1002/ejp.1616)] [Medline: [32533892](https://pubmed.ncbi.nlm.nih.gov/32533892/)]
13. Tang NKY, Crane C. Suicidality in chronic pain: a review of the prevalence, risk factors and psychological links. *Psychol Med* 2006 May;36(5):575-586. [doi: [10.1017/S0033291705006859](https://doi.org/10.1017/S0033291705006859)] [Medline: [16420727](https://pubmed.ncbi.nlm.nih.gov/16420727/)]
14. The cost of pain in Australia. Deloitte Access Economics. 2019. URL: <https://www2.deloitte.com/au/en/pages/economics/articles/cost-pain-australia.html> [accessed 2023-08-18]
15. Institute of Medicine. *Relieving Pain in America: A Blueprint for Transforming Prevention, Care, Education, and Research*. Washington, DC: National Academies Press; 2011.
16. Wolff R, Clar C, Lerch C, Kleijnen J. Epidemiology of chronic non-malignant pain in Germany. *Schmerz* 2011 Feb;25(1):26-44. [doi: [10.1007/s00482-010-1011-2](https://doi.org/10.1007/s00482-010-1011-2)] [Medline: [21336883](https://pubmed.ncbi.nlm.nih.gov/21336883/)]

17. Breivik H, Collett B, Ventafridda V, Cohen R, Gallacher D. Survey of chronic pain in Europe: prevalence, impact on daily life, and treatment. *Eur J Pain* 2006 May;10(4):287-333. [doi: [10.1016/j.ejpain.2005.06.009](https://doi.org/10.1016/j.ejpain.2005.06.009)] [Medline: [16095934](https://pubmed.ncbi.nlm.nih.gov/16095934/)]
18. Dietl M, Korczak D. Versorgungssituation in der Schmerztherapie in Deutschland im internationalen Vergleich hinsichtlich Über-, Unter- oder Fehlversorgung. Schriftenreihe Health Technology Assessment (HTA) in der Bundesrepublik Deutschland. German Institute of Medical Documentation and Information (DIMDI). 2011. URL: https://portal.dimdi.de/de/hta/hta_berichte/hta301_bericht_de.pdf [accessed 2024-04-22]
19. ACPA Stanford Resource Guide to Chronic Pain Management. Stanford Medicine. 2021. URL: <https://med.stanford.edu/content/dam/sm/pain/documents/ACPA-Stanford-Resource-Guide-to-Chronic-Pain-Management-2021-Edition-4-18-21-.pdf> [accessed 2024-04-22]
20. Trost Z, France C, Anam M, Shum C. Virtual reality approaches to pain: toward a state of the science. *Pain* 2021 Feb 01;162(2):325-331. [doi: [10.1097/j.pain.0000000000002060](https://doi.org/10.1097/j.pain.0000000000002060)] [Medline: [32868750](https://pubmed.ncbi.nlm.nih.gov/32868750/)]
21. Goudman L, Jansen J, Billot M, Vets N, De Smedt A, Roulaud M, et al. Virtual reality applications in chronic pain management: systematic review and meta-analysis. *JMIR Serious Games* 2022 May 10;10(2):e34402. [doi: [10.2196/34402](https://doi.org/10.2196/34402)] [Medline: [35536641](https://pubmed.ncbi.nlm.nih.gov/35536641/)]
22. Van Damme S, Legrain V, Vogt J, Crombez G. Keeping pain in mind: a motivational account of attention to pain. *Neurosci Biobehav Rev* 2010 Feb;34(2):204-213. [doi: [10.1016/j.neubiorev.2009.01.005](https://doi.org/10.1016/j.neubiorev.2009.01.005)] [Medline: [19896002](https://pubmed.ncbi.nlm.nih.gov/19896002/)]
23. Hoffman HG. Interacting with virtual objects via embodied avatar hands reduces pain intensity and diverts attention. *Sci Rep* 2021 May 21;11(1):10672. [doi: [10.1038/s41598-021-89526-4](https://doi.org/10.1038/s41598-021-89526-4)] [Medline: [34021173](https://pubmed.ncbi.nlm.nih.gov/34021173/)]
24. Riva G, Wiederhold BK, Mantovani F. Neuroscience of virtual reality: from virtual exposure to embodied medicine. *Cyberpsychol Behav Soc Netw* 2019 Jan;22(1):82-96. [doi: [10.1089/cyber.2017.29099.gri](https://doi.org/10.1089/cyber.2017.29099.gri)] [Medline: [30183347](https://pubmed.ncbi.nlm.nih.gov/30183347/)]
25. Hennessy RW, Rumble D, Christian M, Brown DA, Trost Z. A graded exposure, locomotion-enabled virtual reality app during walking and reaching for individuals with chronic low back pain: cohort gaming design. *JMIR Serious Games* 2020 Aug 10;8(3):e17799. [doi: [10.2196/17799](https://doi.org/10.2196/17799)] [Medline: [32773381](https://pubmed.ncbi.nlm.nih.gov/32773381/)]
26. Tack C. Virtual reality and chronic low back pain. *Disabil Rehabil Assist Technol* 2021 Aug;16(6):637-645. [doi: [10.1080/17483107.2019.1688399](https://doi.org/10.1080/17483107.2019.1688399)] [Medline: [31746250](https://pubmed.ncbi.nlm.nih.gov/31746250/)]
27. Glegg SMN, Levac DE. Barriers, facilitators and interventions to support virtual reality implementation in rehabilitation: a scoping review. *PM R* 2018 Nov;10(11):1237-1251. [doi: [10.1016/j.pmrj.2018.07.004](https://doi.org/10.1016/j.pmrj.2018.07.004)] [Medline: [30503231](https://pubmed.ncbi.nlm.nih.gov/30503231/)]
28. Hung L, Mann J, Wallsworth C, Upreti M, Kan W, Temirova A, et al. Facilitators and barriers to using virtual reality and its impact on social engagement in aged care settings: a scoping review. *Gerontol Geriatr Med* 2023 Apr 01;9:23337214231166355. [doi: [10.1177/23337214231166355](https://doi.org/10.1177/23337214231166355)] [Medline: [37020921](https://pubmed.ncbi.nlm.nih.gov/37020921/)]
29. Kouijzer MMTE, Kip H, Bouman YHA, Kelders SM. Implementation of virtual reality in healthcare: a scoping review on the implementation process of virtual reality in various healthcare settings. *Implement Sci Commun* 2023 Jun 16;4(1):67. [doi: [10.1186/s43058-023-00442-2](https://doi.org/10.1186/s43058-023-00442-2)] [Medline: [37328858](https://pubmed.ncbi.nlm.nih.gov/37328858/)]
30. Brepohl PCA, Leite H. Virtual reality applied to physiotherapy: a review of current knowledge. *Virtual Reality* 2022 Jul 22;27(1):71-95. [doi: [10.1007/s10055-022-00654-2](https://doi.org/10.1007/s10055-022-00654-2)]
31. Clauw DJ, Essex MN, Pitman V, Jones KD. Reframing chronic pain as a disease, not a symptom: rationale and implications for pain management. *Postgrad Med* 2019 Apr;131(3):185-198. [doi: [10.1080/00325481.2019.1574403](https://doi.org/10.1080/00325481.2019.1574403)] [Medline: [30700198](https://pubmed.ncbi.nlm.nih.gov/30700198/)]
32. Moriarty O, McGuire BE, Finn DP. The effect of pain on cognitive function: a review of clinical and preclinical research. *Prog Neurobiol* 2011 Mar;93(3):385-404. [doi: [10.1016/j.pneurobio.2011.01.002](https://doi.org/10.1016/j.pneurobio.2011.01.002)] [Medline: [21216272](https://pubmed.ncbi.nlm.nih.gov/21216272/)]
33. Cane J, O'Connor D, Michie S. Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implement Sci* 2012 Apr 24;7:37. [doi: [10.1186/1748-5908-7-37](https://doi.org/10.1186/1748-5908-7-37)] [Medline: [22530986](https://pubmed.ncbi.nlm.nih.gov/22530986/)]
34. Al Zoubi FM, French SD, Patey AM, Mayo NE, Bussi eres AE. Professional barriers and facilitators to using stratified care approaches for managing non-specific low back pain: a qualitative study with Canadian physiotherapists and chiropractors. *Chiropr Man Therap* 2019 Dec 13;27(1):68. [doi: [10.1186/s12998-019-0286-3](https://doi.org/10.1186/s12998-019-0286-3)] [Medline: [31857892](https://pubmed.ncbi.nlm.nih.gov/31857892/)]
35. Wright C, Kelly JT, Campbell KL, Healy R, Musial J, Hamilton K. A mixed-method study to inform the development and implementation of eHealth in a bariatric surgery service in an Australian public hospital. *Nutr Diet* 2023 Sep;80(4):425-434. [doi: [10.1111/1747-0080.12812](https://doi.org/10.1111/1747-0080.12812)] [Medline: [37096344](https://pubmed.ncbi.nlm.nih.gov/37096344/)]
36. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Method* 2005 Feb;8(1):19-32. [doi: [10.1080/1364557032000119616](https://doi.org/10.1080/1364557032000119616)]
37. Peters MDJ, Marnie C, Tricco AC, Pollock D, Munn Z, Alexander L, et al. Updated methodological guidance for the conduct of scoping reviews. *JBI Evid Synth* 2020 Oct;18(10):2119-2126. [doi: [10.11124/JBIES-20-00167](https://doi.org/10.11124/JBIES-20-00167)] [Medline: [33038124](https://pubmed.ncbi.nlm.nih.gov/33038124/)]
38. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med* 2018 Oct 02;169(7):467-473. [doi: [10.7326/M18-0850](https://doi.org/10.7326/M18-0850)] [Medline: [30178033](https://pubmed.ncbi.nlm.nih.gov/30178033/)]
39. Barriers and facilitators to the implementation of virtual reality in chronic pain: a scoping review. *Open Science Framework*. URL: <https://osf.io/ma983> [accessed 2024-04-22]

40. Kohl C, McIntosh EJ, Unger S, Haddaway NR, Kecke S, Schiemann J, et al. Online tools supporting the conduct and reporting of systematic reviews and systematic maps: a case study on CADIMA and review of existing tools. *Environ Evid* 2018 Feb 1;7(1):8. [doi: [10.1186/s13750-018-0115-5](https://doi.org/10.1186/s13750-018-0115-5)]
41. Peters M, Godfrey C, McInerney P, Munn Z, Trico A, Khalil H. Chapter 11: Scoping reviews. In: Aromataris E E, Munn Z, editors. *JBI Manual for Evidence Synthesis*. Adelaide, Australia: JBI; 2020:406-451.
42. Weatherson KA, Gainforth HL, Jung ME. A theoretical analysis of the barriers and facilitators to the implementation of school-based physical activity policies in Canada: a mixed methods scoping review. *Implement Sci* 2017 Mar 27;12(1):41. [doi: [10.1186/s13012-017-0570-3](https://doi.org/10.1186/s13012-017-0570-3)] [Medline: [28347322](https://pubmed.ncbi.nlm.nih.gov/28347322/)]
43. Tuck N, Pollard C, Good C, Williams C, Lewis G, Hames M, et al. Active virtual reality for chronic primary pain: mixed methods randomized pilot study. *JMIR Form Res* 2022 Jul 13;6(7):e38366. [doi: [10.2196/38366](https://doi.org/10.2196/38366)] [Medline: [35830224](https://pubmed.ncbi.nlm.nih.gov/35830224/)]
44. Sarkar TD, Edwards RR, Baker N. The feasibility and effectiveness of virtual reality meditation on reducing chronic pain for older adults with knee osteoarthritis. *Pain Pract* 2022 Sep;22(7):631-641. [doi: [10.1111/papr.13144](https://doi.org/10.1111/papr.13144)] [Medline: [35750655](https://pubmed.ncbi.nlm.nih.gov/35750655/)]
45. Glavare M, Stålnacke BM, Häger CK, Löfgren M. Virtual reality exercises in an interdisciplinary rehabilitation programme for persons with chronic neck pain: a feasibility study. *J Rehabil Med Clin Commun* 2021;4:1000067. [doi: [10.2340/20030711-1000067](https://doi.org/10.2340/20030711-1000067)] [Medline: [34527201](https://pubmed.ncbi.nlm.nih.gov/34527201/)]
46. Brown L, Chen ET, Binder DS. The use of virtual reality for Peri-procedural pain and anxiety at an outpatient spine clinic injection visit: an exploratory controlled randomized trial. *Am J Transl Res* 2020;12(9):5818-5826. [Medline: [33042461](https://pubmed.ncbi.nlm.nih.gov/33042461/)]
47. Venuturupalli RS, Chu T, Vicari M, Kumar A, Fortune N, Spielberg B. Virtual reality-based biofeedback and guided meditation in rheumatology: a pilot study. *ACR Open Rheumatol* 2019 Dec;1(10):667-675. [doi: [10.1002/acr2.11092](https://doi.org/10.1002/acr2.11092)] [Medline: [31872189](https://pubmed.ncbi.nlm.nih.gov/31872189/)]
48. Garrett B, Taverner T, McDade P. Virtual reality as an adjunct home therapy in chronic pain management: an exploratory study. *JMIR Med Inform* 2017 May 11;5(2):e11. [doi: [10.2196/medinform.7271](https://doi.org/10.2196/medinform.7271)] [Medline: [28495661](https://pubmed.ncbi.nlm.nih.gov/28495661/)]
49. Tong X, Jin W, Cruz K, Gromala D, Garret B, Taverner T. A case study: chronic pain patients' preferences for virtual reality games for pain distraction. In: Chen JYC, Fragomeni G, editors. *Virtual, Augmented and Mixed Reality: Applications in Health, Cultural Heritage, and Industry*. VAMR 2018. Lecture Notes in Computer Science(), vol 10910. Cham: Springer; 2018:3-11.
50. Vugts MAP, Joosen MCW, van Bergen AHMM, Vrijhoef HJM. Feasibility of applied gaming during interdisciplinary rehabilitation for patients with complex chronic pain and fatigue complaints: a mixed-methods study. *JMIR Serious Games* 2016 Apr 01;4(1):e2. [doi: [10.2196/games.5088](https://doi.org/10.2196/games.5088)] [Medline: [27036094](https://pubmed.ncbi.nlm.nih.gov/27036094/)]
51. Kelly JM, Coppieters MW, Kluver J, Deen M, Rio E, Harvie DS. "It made you feel like you've still got it": experiences of people with chronic low back pain undertaking a single session of body image training in virtual reality. *Physiother Theory Pract* 2023 Dec 02;39(12):2651-2661. [doi: [10.1080/09593985.2022.2095313](https://doi.org/10.1080/09593985.2022.2095313)] [Medline: [35861952](https://pubmed.ncbi.nlm.nih.gov/35861952/)]
52. Stamm O, Dahms R, Müller-Werdan U. Virtual reality in pain therapy: a requirements analysis for older adults with chronic back pain. *J Neuroeng Rehabil* 2020 Sep 29;17(1):129. [doi: [10.1186/s12984-020-00753-8](https://doi.org/10.1186/s12984-020-00753-8)] [Medline: [32993678](https://pubmed.ncbi.nlm.nih.gov/32993678/)]
53. Garrett BM, Tao G, Taverner T, Cordingley E, Sun C. Patients perceptions of virtual reality therapy in the management of chronic cancer pain. *Heliyon* 2020 May;6(5):e03916. [doi: [10.1016/j.heliyon.2020.e03916](https://doi.org/10.1016/j.heliyon.2020.e03916)] [Medline: [32426540](https://pubmed.ncbi.nlm.nih.gov/32426540/)]
54. Mortensen J, Kristensen LQ, Brooks EP, Brooks AL. Women with fibromyalgia's experience with three motion-controlled video game consoles and indicators of symptom severity and performance of activities of daily living. *Disabil Rehabil Assist Technol* 2015 Jan;10(1):61-66. [doi: [10.3109/17483107.2013.836687](https://doi.org/10.3109/17483107.2013.836687)] [Medline: [24028282](https://pubmed.ncbi.nlm.nih.gov/24028282/)]
55. Beltran-Alacreu H, Navarro-Fernández G, Godia-Lledó D, Graell-Pasarón L, Ramos-González Á, Raya R, et al. A serious game for performing task-oriented cervical exercises among older adult patients with chronic neck pain: development, suitability, and crossover pilot study. *JMIR Serious Games* 2022 Feb 01;10(1):e31404. [doi: [10.2196/31404](https://doi.org/10.2196/31404)] [Medline: [35103608](https://pubmed.ncbi.nlm.nih.gov/35103608/)]
56. Liu K, Madrigal E, Chung JS, Parekh M, Kalahar CS, Nguyen D, et al. Preliminary study of virtual-reality-guided meditation for Veterans with stress and chronic pain. *Altern Ther Health Med* 2023 Sep;29(6):42-49. [Medline: [34559692](https://pubmed.ncbi.nlm.nih.gov/34559692/)]
57. Spiegel B. *VRx: How Virtual Therapeutics Will Revolutionize Medicine*. New York: Basic Books; 2020.
58. Birkhead B, Khalil C, Liu X, Conovitz S, Rizzo A, Danovitch I, et al. Recommendations for methodology of virtual reality clinical trials in health care by an international working group: iterative study. *JMIR Ment Health* 2019 Jan 31;6(1):e11973. [doi: [10.2196/11973](https://doi.org/10.2196/11973)] [Medline: [30702436](https://pubmed.ncbi.nlm.nih.gov/30702436/)]
59. Bushnell MC, Ceko M, Low LA. Cognitive and emotional control of pain and its disruption in chronic pain. *Nat Rev Neurosci* 2013 Jul;14(7):502-511. [doi: [10.1038/nrn3516](https://doi.org/10.1038/nrn3516)] [Medline: [23719569](https://pubmed.ncbi.nlm.nih.gov/23719569/)]
60. Konttila J, Siira H, Kyngäs H, Lahtinen M, Elo S, Kääriäinen M, et al. Healthcare professionals' competence in digitalisation: a systematic review. *J Clin Nurs* 2019 Mar;28(5-6):745-761. [doi: [10.1111/jocn.14710](https://doi.org/10.1111/jocn.14710)] [Medline: [30376199](https://pubmed.ncbi.nlm.nih.gov/30376199/)]
61. Koivunen M, Anttila M, Kuosmanen L, Katajisto J, Välimäki M. Team climate and attitudes toward information and communication technology among nurses on acute psychiatric wards. *Inform Health Soc Care* 2015 Jan 06;40(1):79-90. [doi: [10.3109/17538157.2013.872112](https://doi.org/10.3109/17538157.2013.872112)] [Medline: [24393065](https://pubmed.ncbi.nlm.nih.gov/24393065/)]
62. Hayden JA, Wilson MN, Riley RD, Iles R, Pincus T, Ogilvie R. Individual recovery expectations and prognosis of outcomes in non-specific low back pain: prognostic factor review. *Cochrane Database Syst Rev* 2019 Nov 25;2019(11):CD011284. [doi: [10.1002/14651858.CD011284.pub2](https://doi.org/10.1002/14651858.CD011284.pub2)] [Medline: [31765487](https://pubmed.ncbi.nlm.nih.gov/31765487/)]

63. World Health Organization. Adherence to Long-Term Therapies: Evidence for Action. Geneva: World Health Organization; 2003.
64. Vermeire E, Hearnshaw H, Van Royen P, Denekens J. Patient adherence to treatment: three decades of research. A comprehensive review. *J Clin Pharm Ther* 2001 Oct;26(5):331-342. [doi: [10.1046/j.1365-2710.2001.00363.x](https://doi.org/10.1046/j.1365-2710.2001.00363.x)] [Medline: [11679023](https://pubmed.ncbi.nlm.nih.gov/11679023/)]
65. Hayden JA, Ellis J, Ogilvie R, Stewart SA, Bagg MK, Stanojevic S, et al. Some types of exercise are more effective than others in people with chronic low back pain: a network meta-analysis. *J Physiother* 2021 Oct;67(4):252-262. [doi: [10.1016/j.jphys.2021.09.004](https://doi.org/10.1016/j.jphys.2021.09.004)] [Medline: [34538747](https://pubmed.ncbi.nlm.nih.gov/34538747/)]
66. Flor H. Pain has an element of blank-a biobehavioral approach to chronicity. *Pain* 2017 Apr 18;158(Suppl 1):S92-S96. [doi: [10.1097/j.pain.0000000000000850](https://doi.org/10.1097/j.pain.0000000000000850)] [Medline: [28114184](https://pubmed.ncbi.nlm.nih.gov/28114184/)]

Abbreviations

ECR: environmental context and research

PRISMA-ScR: Preferred Reporting Items of Systematic Reviews and Meta-Analyses extension for Scoping Reviews.

SMD: standardized mean difference

TDF: Theoretical Domains Framework

VR: virtual reality

Edited by T Leung; submitted 27.09.23; peer-reviewed by K Kammler-Sückler, B Elsner, D Liu; comments to author 13.03.24; revised version received 12.04.24; accepted 17.04.24; published 15.05.24.

Please cite as:

Elser A, Lange M, Kopkow C, Schäfer AG

Barriers and Facilitators to the Implementation of Virtual Reality Interventions for People With Chronic Pain: Scoping Review

JMIR XR Spatial Comput 2024;1:e53129

URL: <https://xr.jmir.org/2024/1/e53129>

doi: [10.2196/53129](https://doi.org/10.2196/53129)

PMID:

©Alexander Elser, Marina Lange, Christian Kopkow, Axel Georg Schäfer. Originally published in JMIR XR and Spatial Computing (<https://xr.jmir.org>), 15.05.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR XR and Spatial Computing, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Editorial

Discovering and Creating the Leading Edge of Extended Reality and Spatial Computing: A Message From the Editor-in-Chief

Lars Riedemann¹, MD

Department of Neurology, Heidelberg University Hospital, Heidelberg, Germany

Corresponding Author:

Lars Riedemann, MD

Department of Neurology

Heidelberg University Hospital

Im Neuenheimer Feld 400

Heidelberg, 69120

Germany

Phone: 49 6221 56 6999

Email: lars.riedemann@med.uni-heidelberg.de

Abstract

We are pleased to introduce *JMIR XR and Spatial Computing*, a peer-reviewed journal dedicated to advancing the integration of extended reality and spatial computing technologies into routine clinical care.

(*JMIR XR Spatial Comput* 2024;1:e64545) doi:[10.2196/64545](https://doi.org/10.2196/64545)

KEYWORDS

editorial; extended reality; XR; spatial computing

We are excited to announce the launch of *JMIR XR and Spatial Computing*, a peer-reviewed journal dedicated to showcasing research on extended reality (XR) and spatial computing technologies and their integration into everyday clinical practice.

In navigating the frontier of XR and spatial computing for more than a decade, we have adopted a stance of informed optimism tempered by vigilant caution. Based on the large number of high-quality articles published by JMIR Publications and others over the last decades, the tremendous potential of these technologies to enhance diagnostic precision, increase treatment efficacy, facilitate easier access to care, and—most importantly—improve patient outcomes seem obvious. Yet, we remain cognizant that their integration into the health care ecosystem is not without peril and may take longer than many researchers and technologists have expected. We anticipate that immersive technologies will transition from a novel solution to an established standard in targeted medical scenarios. However, integration into complex health care systems and widespread acceptance by health care workers will not happen overnight. Not unlike other established technologies, we expect a slow and stepwise adoption as a result of candid discussions within the community, and rigorous, basic, translational, and clinical research [1].

XR and spatial computing are relatively old concepts, dating back to at least the late 1960s; they became visible to the scientific community through iconic works such as Ivan Sutherland's *The Sword of Damocles* [2]. In 2003, Simon

Greenwold at the Massachusetts Institute of Technology described “spatial computing” in his thesis as a “human interaction with a machine in which the machine retains and manipulates referents to real objects and spaces” [3]. Inspired by prior researchers and technologists, he foresaw that “the augmentation of a data network with a physical network promotes the flow of digital information on top of existing social interactions” [3].

When JMIR Publications launched in 1999, the widespread adoption of XR and spatial computing in clinical settings was hard to imagine. Fast forward to today, and we find ourselves at the cusp of an era where XR and spatial computing are poised for integration into routine clinical care. This shift has been propelled by a confluence of recent technological advancements. The rapid artificial intelligence (AI) evolution [4], particularly breakthroughs in computer vision, has significantly improved spatial mapping and 3D scene understanding. Furthermore, AI has truly revolutionized programming code and 3D content creation. Exponential improvements in graphical processing capabilities [5] have been complemented by significant advances in lightweight, energy-efficient display technologies [6], and the advent of high-bandwidth and low-latency networks has significantly enhanced connectivity. The decreasing costs of XR technology and its growing popularity among consumers continue to lower adoption barriers for XR and spatial computing in health care.

The tangible impact of these developments in health care is evident. For instance, Bandelow et al [7], who authored the German guideline for treating anxiety disorders, recommend virtual reality exposure therapy as a viable alternative when in vivo exposure is not feasible for patients with spider, height, or flight phobias. Furthermore, the US Food and Drug Administration has reviewed and authorized the marketing of a growing number of devices with augmented reality and virtual reality through 510(k) clearance, De Novo requests, or premarket approval in many fields of medicine [8].

These examples illustrate the growing acceptance of immersive technologies in clinical practice as “another arrow in the quiver” of health care.

However, our optimism is tempered with pragmatism. Although XR and spatial computing offer promising avenues for enhancing health care delivery, we recognize that they are not universal solutions. The successful integration of these technologies into existing health care systems and workflows requires thoughtful consideration and careful implementation [8]. Their true effectiveness will be determined by the appropriateness of their application, the specific contexts in which they are deployed, a significantly positive cost-benefit ratio, and most importantly, their demonstrable ability to improve patient outcomes or enhance health care efficiency [8,9]. As we move forward, it is crucial to approach the adoption of these technologies with a balanced perspective, ensuring that their integration complements and enhances, rather than disrupts, the foundational aspects of quality health care delivery.

Therefore, we encourage authors from both academia and industry to view *JMIR XR and Spatial Computing* as a platform for showcasing their collaborative efforts, sharing insights, and

contributing to the responsible advancement of immersive technologies in health care.

Our journal recognizes the critical importance of addressing the accessibility and equity challenges surrounding XR and spatial computing technologies. We strongly encourage the community to submit manuscripts exploring innovative solutions to these pressing issues. We are particularly interested in studies on cost-effective technology implementations in resource-limited settings and strategies for overcoming infrastructure barriers in underserved areas. By fostering dialogue and research in this area, we aim to ensure that the transformative potential of XR and spatial computing technologies benefits the entire international community.

Central to our vision is the belief in the power of strong academic-industrial collaborations. These collaborations bridge the gap between theoretical research and practical application, accelerating the development of cutting-edge XR and spatial computing solutions while ensuring they meet rigorous scientific standards. Therefore, we actively encourage and facilitate partnerships between academic researchers and industry innovators. Furthermore, we invite independent, nonacademic developers and designers as well as open-source project contributors of all kinds to communicate their perspectives with us. We believe that the transparency and accessibility of open-source development can significantly accelerate progress in XR and spatial computing applications for health care.

By embracing contributions from this diverse range of sources—academic-industrial collaborations, individual innovators, and open-source communities—we aim to foster a rich ecosystem of ideas and developments that will shape the future of XR and spatial computing in health care.

Acknowledgments

The author used generative AI for proof reading and style. The conceptual work as well as the choice of references and citations were solely made by the author, untouched by AI.

Conflicts of Interest

LR is the editor-in-chief of *JMIR XR and Spatial Computing*. He is also a stakeholder in Shift Medical GmbH.

References

1. Freyer O, Gilbert S. Bridging between hype and implementation in medical extended reality. *NPJ Digit Med* 2023 Dec 07;6(1):227 [FREE Full text] [doi: [10.1038/s41746-023-00972-y](https://doi.org/10.1038/s41746-023-00972-y)] [Medline: [38062115](https://pubmed.ncbi.nlm.nih.gov/38062115/)]
2. Sutherland IE. A head-mounted three dimensional display. In: Proceedings of the December 9-11, 1968, Fall Joint Computer Conference, Part I. 1968 Presented at: AFIPS '68; Dec 9-11, 1968; San Francisco, CA p. 9-11. [doi: [10.1145/1476589.1476686](https://doi.org/10.1145/1476589.1476686)]
3. Greenwold S. Spatial Computing [Master's thesis]. Massachusetts Institute of Technology. 2003. URL: <https://acg.media.mit.edu/people/simong/thesis/SpatialComputing.pdf> [accessed 2024-07-19]
4. Haug CJ, Drazen JM. Artificial intelligence and machine learning in clinical medicine, 2023. *N Engl J Med* 2023 Mar 30;388(13):1201-1208. [doi: [10.1056/nejmra2302038](https://doi.org/10.1056/nejmra2302038)]
5. Garisto D. How cutting-edge computer chips are speeding up the AI revolution. *Nature* 2024 Jun 04;630(8017):544-546. [doi: [10.1038/d41586-024-01544-0](https://doi.org/10.1038/d41586-024-01544-0)] [Medline: [38834691](https://pubmed.ncbi.nlm.nih.gov/38834691/)]
6. Xiong J, Hsiang E, He Z, Zhan T, Wu S. Augmented reality and virtual reality displays: emerging technologies and future perspectives. *Light Sci Appl* 2021 Oct 25;10(1):216 [FREE Full text] [doi: [10.1038/s41377-021-00658-8](https://doi.org/10.1038/s41377-021-00658-8)] [Medline: [34697292](https://pubmed.ncbi.nlm.nih.gov/34697292/)]

7. Bandelow B, Aden I, Alpers GW, Andreassen AO, Arolt V, Beutel ME, et al. S3-Leitlinie Behandlung von Angststörungen [German S3 guideline for the treatment of anxiety disorders]; version 2. AWMF. 2021. URL: <https://register.awmf.org/de/leitlinien/detail/051-028> [accessed 2024-07-19]
8. Beams R, Brown E, Cheng WC, Joyner JS, Kim AS, Kontson K, et al. Evaluation challenges for the application of extended reality devices in medicine. *J Digit Imaging* 2022 Oct;35(5):1409-1418 [FREE Full text] [doi: [10.1007/s10278-022-00622-x](https://doi.org/10.1007/s10278-022-00622-x)] [Medline: [35469355](https://pubmed.ncbi.nlm.nih.gov/35469355/)]
9. Selaskowski B, Wiebe A, Kannen K, Asché L, Pakos J, Philipsen A, et al. Clinical adoption of virtual reality in mental health is challenged by lack of high-quality research. *npj Ment Health Res* 2024 May 16;3(1):24 [FREE Full text] [doi: [10.1038/s44184-024-00069-8](https://doi.org/10.1038/s44184-024-00069-8)] [Medline: [38755289](https://pubmed.ncbi.nlm.nih.gov/38755289/)]

Abbreviations

AI: artificial intelligence

XR: extended reality

Edited by T Leung; submitted 19.07.24; this is a non-peer-reviewed article; accepted 19.07.24; published 26.07.24.

Please cite as:

Riedemann L

Discovering and Creating the Leading Edge of Extended Reality and Spatial Computing: A Message From the Editor-in-Chief

JMIR XR Spatial Comput 2024;1:e64545

URL: <https://xr.jmir.org/2024/1/e64545>

doi: [10.2196/64545](https://doi.org/10.2196/64545)

PMID:

©Lars Riedemann. Originally published in *JMIR XR and Spatial Computing* (<https://xr.jmir.org>), 26.07.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in *JMIR XR and Spatial Computing*, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Original Paper

Using Virtual Reality to Reduce Stress in Adolescents: Mixed Methods Usability Study

Elin A Björ ling¹, PhD; Jennifer Sonney², PhD; Himanshu Zade¹, MS; Sofia Rodriguez¹, MS; Michael D Pullmann³, PhD; Soo Hyun Moon¹, MS

¹Human Centered Design and Engineering, University of Washington, Seattle, WA, United States

²Child, Family, and Population Health Nursing, University of Washington, Seattle, WA, United States

³Psychiatry & Behavioral Sciences, University of Washington, Seattle, WA, United States

Corresponding Author:

Elin A Björ ling, PhD

Human Centered Design and Engineering

University of Washington

428 Sieg Hall

Campus Box 352315

Seattle, WA, 98195

United States

Phone: 1 206 606 2662

Email: bjorling@uw.edu

Abstract

Background: Adolescent mental health is a national mental health emergency amid surging rates of anxiety and depression. Given the scarcity and lack of scalable mental health services, the use of self-administered, evidence-based technologies to support adolescent mental health is both timely and imperative.

Objective: The goal of this study was 2-fold: (1) to determine the feasibility, usability, and engagement of a participatory designed, nature-based virtual reality (VR) environment and (2) to determine the preliminary outcomes of our self-administered VR environment on depression, mindfulness, perceived stress, and momentary stress and mood.

Methods: We conducted a within-person, 3-week, in-home study with a community-based sample of 44 adolescents. Participants completed surveys of perceived stress, depression, cognitive fusion, and mindfulness at intake, postintervention, and a 3-week follow-up. Participants were invited to use a nature-based, VR environment that included 6 evidence-based activities 3 to 5 times per week. They completed momentary stress and mood surveys 5 times each day and before and after each VR session. Postintervention, participants completed surveys on system and intervention usability and their experiences with using the VR system. Quantitative data were analyzed using descriptive statistics and mixed effects modeling to explore the effect of the VR environment on stress. Qualitative data were analyzed using collaborative thematic analysis.

Results: Participants' use of the VR environment ranged from 1 session to 24 sessions (mean 6.27 sessions) at home over a 3-week period. The 44 participants completed all study protocols, indicating our protocol was feasible and the VR environment was engaging for most. Both the use of the VR system and novel VR intervention received strong usability ratings (mean 74.87 on the System Usability Scale). Most teens indicated that they found the tool to be easily administered, relaxing, and helpful with stress. For some, it offered space to process difficult emotions. The themes *calm*, *regulating*, and *forget about everything* resulted from open-ended exit interview data. Although the Relaxation Environment for Stress in Teens (RESeT) did not significantly affect repeated survey measurements of depression, mindfulness, nor cognitive fusion, it did positively affect momentary mood (pre-intervention: 10.8, post-intervention: 12.0, $P=.001$) and decrease momentary stress (pre-intervention: 37.9, post-intervention: 20.6, $P=.001$). We found a significant reduction in within-day momentary stress that strengthened with increased VR use over time during the study period ($P=.03$).

Conclusions: These preliminary data inform our own VR environment design but also provide evidence of the potential for self-administered VR as a promising tool to support adolescent mental health. Self-administered VR for mental health may be an effective intervention for reducing adolescent stress. However, understanding barriers (including disengagement) to using VR, as well as further encouraging participatory design with teens, may be imperative to the success of future mental health interventions.

KEYWORDS

virtual reality; adolescents; perceived stress; participatory design; depression

Introduction

It is good to like, to have the brain stop for a second and focus on small things. [P98, girl, 16 years old, exit interview]

The Potential for Virtual Reality in Adolescent Mental Health

In a 2018 American Psychological Association survey [1], teens reported worse mental health and higher levels of anxiety and depression than all other age groups. Increased stress causes adverse mental and physical outcomes, including anxiety and depression [2]. However, despite effective, evidence-based treatments for adverse outcomes associated with stress [3], only one-half of teens will receive mental health services due to mental health provider shortages and other barriers to accessing care [4,5]. Even worse, evidence-based therapies are often inaccessible due to cost, time, or the need for a trained interventionist [6]. Therefore, a self-administered, technology-based solution could increase accessibility and scalability of these therapies.

Virtual reality (VR)-based serious games (SGs) for mental health present an opportunity for the translation of effective mental health strategies to an engaging platform [7,8]. VR consists of a head-mounted display that displays simulated environments for exploration and interaction. The immersive and intuitive experience of VR makes it an optimal platform for delivering self-administered SG health interventions for adolescents [9]. Additionally, VR-based SGs are scalable, which could increase accessibility to evidence-based mental health care. VR has been successfully deployed in treating an array of health conditions in adults, including posttraumatic stress disorder [10], phobias [11], and perceived stress in military personnel [12].

The use of VR as an intervention platform for adolescent mental health is an emerging area of inquiry [13,14]. VR has been shown to be acceptable and effective in treating procedural pain, headaches, and public speaking anxiety in adolescents [15-18]. In addition, Björ ling et al [19] found that a nature-based environment reduced stress in teens and that teens will self-administer VR therapeutically. Building on these findings, it has been suggested that existing evidence-based mental health therapies, such as cognitive behavioral theory (CBT), could be translated into a VR environment as an innovative approach to delivering scalable mental health interventions [20]. Although a recent systematic review of clinical trials of mostly computer-based video games found CBT SGs to be more effective than no intervention, true efficacy was clouded by study rigor, and none of the CBT games were VR [21]. In a systematic review of VR environments intended to reduce pain and anxiety in children and adolescents, Ahmadpour et al [22] proposed that future VR interventions explore skill building

and provide dynamic feedback to participants to enable them to be an active participant in managing their own care.

The Importance of Participatory Design

Participatory design (PD) is an approach in which the people who are “destined to use the system play a critical role in designing it” [23]. In PD, the goal is not to simply build systems that address the needs and wants of people. Rather, the hallmark of PD is to establish cooperative and collaborative design relationships that engage users throughout the iterative design process. Research results are often collaboratively interpreted by designer-researchers and the participants who will use the design. For this very reason, gathering data continually during the design and testing phases of development is essential. Such a collaborative approach is thought to result in solutions that address real-world needs and priorities in people’s lives [24,25].

Engaging teens in PD is rare in the design and development of VR, though it is a successful methodology for working with teens in relation to mental health [26-28]. PD is an appropriate approach for designing new technologies with teens due to its meaningful engagement of participants throughout the design process [29,30]. However, engagement is highly variable, and the methods are often iterative and flexible [26]. Examples of engaging teens in co-design for mental health include suicide prevention through social media [27] and stress reduction via a social robot [28]. In fact, co-design with youth specifically for VR has also shown to be successful. Realpe et al [31] engaged youth in the co-design of a virtual environment as a social cognition intervention for people with a first episode of psychosis. Björ ling et al [32] successfully engaged teens in the design of a VR environment aimed to reduce stress.

Our Motivation: A Study of Usability and Experience

As a technology, VR holds the potential to provide immersive experiences and skills training to reinforce evidence-based mental health practices. However, in order to be effective, it must be engaging and usable by teens. Therefore, we designed and developed our VR environment, Relaxation Environment for Stress in Teens (RESeT), using a human-centered, PD approach. We engaged adolescents in each stage of development to ensure usefulness and maximize engagement. Equally important was to empirically measure usability and user experience. Therefore, in our pilot study of our novel VR environment, we explored 2 aims and associated research questions (RQs).

Aim 1

The first aim was to measure the implementation outcomes (feasibility, acceptability, appropriateness, usability, and engagement) of a participatory designed, nature-based VR environment.

- RQ1: How did teens use RESeT, and how did they rate its implementation?
- RQ2: What is the experience of using RESeT?

Aim 2

The second aim was to determine the preliminary mental health outcomes of our self-administered VR environment on depression, mindfulness, perceived stress, and momentary stress and mood.

- RQ3: What effect does RESeT use have on retrospective stress (Perceived Stress Scale [PSS]), depression (Patient Health Questionnaire 9 [PHQ-9]), cognitive fusion (Cognitive Fusion Questionnaire [CFQ]), or mindfulness (Mindfulness Attention and Awareness Scale [MAAS])?
- RQ4: What effect does RESeT use have on momentary stress and mood?
 - RQ4a: Do baseline depression, mindfulness, and stress moderate the effect of [VR environment] on momentary stress over the 3-week intervention?

- RQ4b: Does dosage (frequency and duration of VR use) moderate momentary stress over the 3-week intervention?

Methods

Study Timeline

The prospective, within-person study design utilized multiple layers of measurement. Participants completed surveys at intake, exit, and follow-up as well as within-day momentary measurements of stress and mood and pre- and post-VR measurements. See [Table 1](#) for a summary of the participant activities and measurement over time.

Table 1. Study measurement timeline.

Study activity	Research question (RQ)	Intake	5 times per day during the 3-week intervention	Pre/post-VR ^a use	Exit (at 3 weeks)	Follow-up (at 7 weeks)
Survey instruments						
PHQ-9 ^b (depression)	RQ3	✓			✓	✓
PSS ^c (retrospective stress)	RQ3	✓			✓	✓
CFQ ^d (cognitive fusion)	RQ3	✓			✓	✓
MAAS ^e (mindfulness/attention)	RQ3	✓			✓	✓
SUS ^f /IUS ^g (usability)	RQ1				✓	
IAM ^h , FIM ⁱ , AIM ^j (appropriateness, feasibility, acceptability of intervention)	RQ1				✓	
Interview (user experience)	RQ2				✓	
Momentary instruments						
Stress	RQ4		✓	✓		
Sadness	RQ4		✓			
Affect	RQ4			✓		
Comfort	RQ4			✓		

^aVR: virtual reality.

^bPHQ-9: Patient Health Questionnaire 9.

^cPSS: Perceived Stress Scale.

^dCFQ: Cognitive Fusion Questionnaire.

^eMAAS: Mindfulness Attention and Awareness Scale.

^fSUS: System Usability Scale.

^gIUS: Intervention Usability Questionnaire.

^hIAM: Acceptability of Intervention Measure.

ⁱFIM: Feasibility of Intervention Measure.

^jAIM: Appropriateness of Intervention Measure.

The Development of a Relaxation Environment for Teen Stress

The novel VR RESeT was developed in partnership with teens and the Seattle Public Library. Design of RESeT began by eliciting teen ideas and design principles through PD sessions spanning 2 years with approximately 60 teens at local library

sites. Some of our design-session studies are described in a previous publication [32]. Based upon teen preferences, RESeT was designed as an open, explorable world filled with nature, animals, and calming activities. The activities in RESeT incorporate evidence-based mental health activities stemming from dialectical behavioral therapy [33], acceptance and commitment therapy [34], and mindfulness-based stress

reduction for teens [35]. Each of these therapies have been shown to be very effective in adolescents. Although such self-administered exercises are typically administered in workbooks and worksheets, we incorporated them into the immersive and interactive VR world with teens as our co-designers.

As an example, teens experience “defusion” from negative emotions in the VR environment by placing negative words into a paper boat and releasing the boat out onto a river. As the boat floats away from them, they can reflect on their ability to release negative emotions rather than hold them tightly or be “fused” with them. This process is called *cognitive defusion* [36]. Another example in the environment is building a teen’s capacity for mindfulness through an interaction that invites teens to listen carefully for different birds and look to find where their song is coming from. Integrating these activities was iteratively refined through a series of design sessions (37 teens) and usability testing sessions (9 teens) resulting in a fully

functional RESeT comprised of 6 evidence-based interactions. In addition, the game was designed with arm-swing locomotion where the player swings their arms back and forth to create a natural walking pace in VR. The faster they swing their arms, the faster they move through the environment. Not only is this type of locomotion naturalistic, it has also been shown to improve mood [12].

The RESeT is a natural environment set in winter, consisting of a mountainous border surrounding a snow-covered, tree-filled meadow. A river runs through the meadow, providing a natural border to create an open world feeling for player exploration. A riverboat provides players with a relaxing space in which they can explore and participate in various activities without having a time limit or required objective. Nature sounds and ambient music play in the background through the experience.

Players start the game at a home base location in the middle of the map. See [Figure 1](#) for an illustration.

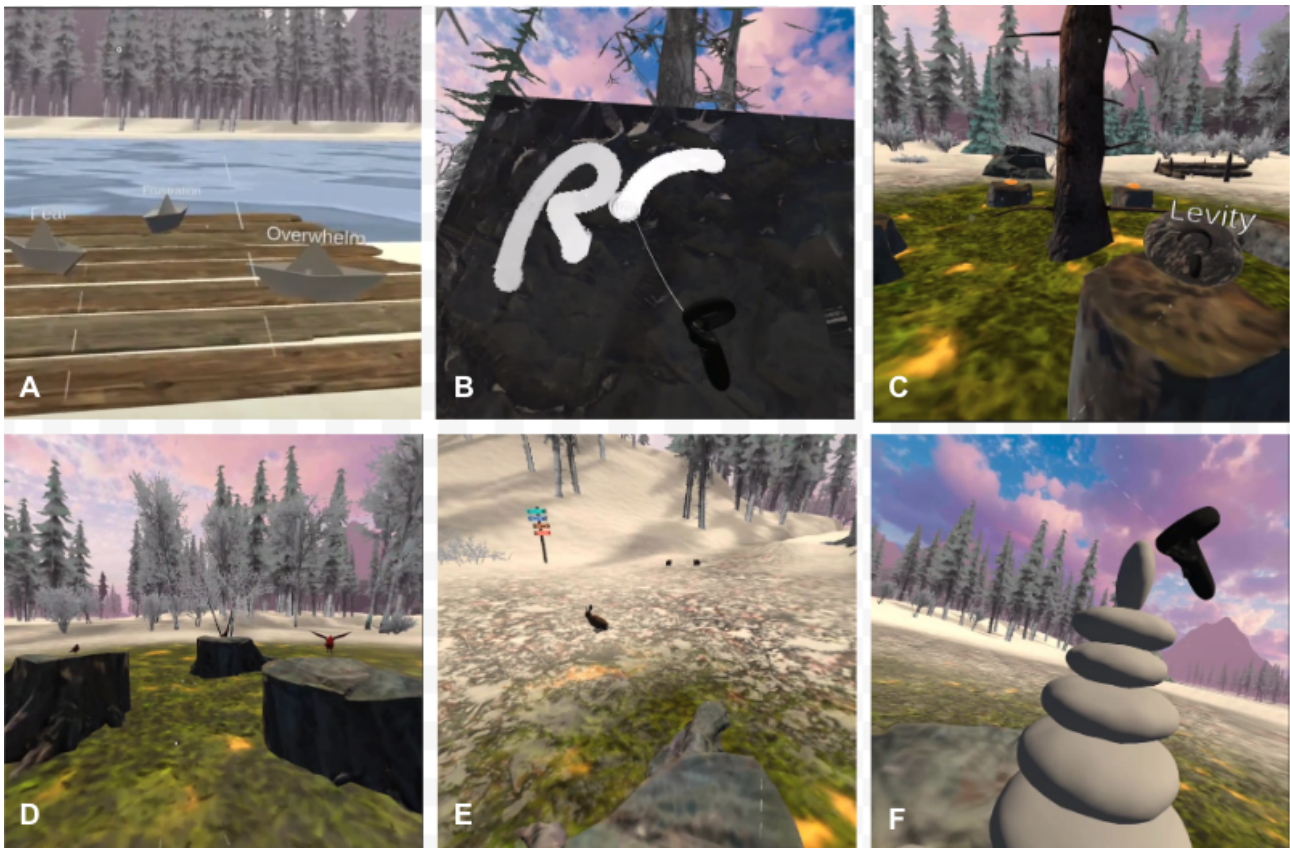
Figure 1. Examples of the (A) controller, (B) wayfinding, and (C) activity navigation.



The environment is designed for seated or standing gameplay using arm-swing navigation intended to feel most like walking. Participants navigate a series of wandering paths and colorful signposts to guide them to 6 clearings, each containing a different activity. See [Figure 2](#) for screenshots during gameplay for each of the 6 activities. In the riverboat activity, players set paper *feeling* boats into the water. Each boat is labeled with a different negative emotion (emotional clarity/cognitive defusion). In the painting activity, players are able to paint on a surface, with their painting slowly disappearing after a short period of time (artful mindfulness). In the scavenger hunt, players search for rocks hidden around the clearing and place

them on stumps when found. Each rock is labeled with a positive word, and when all rocks are found, they change color (visual attention/positive affirmations). With bird search, players search for 3 hidden birds by following the bird’s call. When found, the bird flies to a stump, and when all 3 birds are found, flowers appear (auditory mindfulness). In the rabbit hole activity, players stand still near a stump, and rabbits appear the longer they are standing there (attention/awareness). With rock stacking, players stack rocks on each other to create stacks or other formations (attention/focus). See [Multimedia Appendix 1](#) for a video illustration of the environment.

Figure 2. Screenshots of gameplay illustrating each of the 6 activities: (A) riverboat, (B) painting, (C) scavenger hunt, (D) bird search, (E) rabbit hole, (F) rock stacking.



Ethics Approval

The University of Washington Institutional Review Board approved this study (Study 00003795: Virtual Relaxation Experience).

Recruitment, Screening, and Enrollment

A convenience sample of teens was recruited from April 2021 through June 2021 via social media (Facebook, Twitter), listservs, and snowball sampling. Eligibility criteria included (1) ages 14 years to 18 years, (2) able to speak and read English, (3) have a smartphone with SMS text messaging capabilities, and (4) currently live in the greater metro area. Prospective participants with a diagnosed seizure disorder were excluded from this study due to the risk of VR triggering a seizure.

Research Electronic Data Capture (REDCap) [37], a secure web-based data collection and management system, was used for all participant survey data collection. Prospective participants accessed the REDCap study eligibility screening survey via a QR code or weblink, which described the study aims and associated activities. Eligibility was automatically determined after the individual completed the survey. Those who were eligible were consented within the REDCap system. Participants were informed of the study procedures and phases and that they could disengage at any time. Parents of participants younger than 18 years were sent an email with study contact information.

Upon entering the study, a VR kit was delivered to the participant's home via study staff using a no contact protocol described in a previous study by Sonney et al [38]. Participants

were emailed an enrollment and orientation packet that included a video demonstration of setting up and charging the VR headset. During the study, research staff used text messaging to check in with participants the day they received the VR kit, on day 3, and once a week thereafter. Participants were informed to contact study staff by text if they had any questions.

Instrumentation

Surveys included an investigator-developed questionnaire capturing participant age, grade in school, and prior experience using VR (never, once, 2-5 times, ≥ 6 times) for numerous VR technologies, including standalone headsets, full headsets, and Google cardboard. Participant gender, racial, ethnic, and tribal (if applicable) identities were collected via a write-in option. Standardized surveys focused on implementation outcomes (Aim 1, RQ1) were administered postintervention (Time 2) and included the Acceptability of Intervention Measure, Feasibility of Intervention Measure, Appropriateness of Intervention Measure [39], System Usability Scale (SUS; $\alpha=.85$) [40], and Intervention Usability Scale (IUS) [41]. Surveys focused on mental health outcomes (Aim 2, RQ3) included the PHQ-9 ($\alpha=.89$) [42], PSS ($\alpha=.71-.91$) [43], CFQ ($\alpha=.93$) [44], and MAAS ($\alpha>.80$) [45]. These were administered at intake (Time 1), after the 3-week intervention (Time 2), and 4 weeks postintervention (Time 3). Intake surveys were estimated to take 15 minutes to 20 minutes to complete, and exit surveys were estimated to take 15 minutes to 25 minutes.

Momentary instruments (Aim 2, RQ4) included a 5-time per day momentary survey using SEMA 3 software [46] to gather within-day momentary assessments of stress and mood over the

3-week intervention period. Participants were sent 5 scheduled, within-day mood surveys each day of the 3-week study. Within-day surveys asked 2 questions: “How stressed do you feel right now?” and “How sad do you feel right now?” Participants answered these questions on a sliding scale ranging from no sadness/no stress (0) to extremely sad/extremely stressed (100). In addition, a pre- and post-VR survey was developed that included the same stress scale as the within-day survey. However, it also included an abbreviated Positive and Negative Affect Scale [47] and a comfort scale for post-VR: “How comfortable was your VR session?” (1: not very comfortable to 5: very comfortable). Momentary surveys were estimated to take between 30 seconds and 90 seconds to complete.

Given the potential for participants to forget the self-initiated VR survey, we addressed Aim 1, RQ2 using 2 VR use statistics: VR use frequency (number of sessions) and VR use duration (length of use). These were measured through VR activity metrics downloaded directly from each headset. An analytics system built into RESeT saved a VR use log file with a time stamp and duration for each session. In case the analytics system malfunctioned, the Android OS UsageStatsManager was used to retrieve total app use time from the last 24 hours, 7 days, and 30 days.

Finally, to address Aim 1, RQ2, a semistructured interview examined the participant experience, perceived effect, and feedback related to the protocol and environment (Aim 1). For example, “What did you feel using RESeT?” and “What concerns do you have about using RESeT?” Interviews lasted approximately 15 minutes and were recorded via videoconferencing software. In addition, we asked participants about their likelihood to continue using the environment as well as how they might change the design. The semistructured interview took between 10 minutes and 20 minutes to complete.

Intervention Procedure

Participants were delivered a Quest 2 headset, charger, and customized user manual that included links to troubleshooting and an unboxing video directly to their home. At the start of the study, they were asked to use RESeT for 10 minutes to 15 minutes 3 to 5 times per week. Participants were not further prompted to use the headset nor were they incentivized based upon the amount of headset use during the study. Before each use, they were asked to complete the SEMA presession surveys (stress, affect), explore the RESeT however they desired, and complete the SEMA postsession surveys (stress, affect, comfort). The study team completed weekly check-ins via text message throughout the 3-week pilot and were available for any questions.

At the end of the 3-week pilot, REDCap automatically sent participants the postintervention survey queue, and the study team conducted a semistructured exit interview and scheduled a time to retrieve the VR study kit, which was sanitized and prepared for the next participant. A 3-week follow-up survey queue was automatically sent by REDCap. Participants received digital gift cards after each survey completion. Participants received US \$25 at Time 1, US \$75 at Time 2, and US \$50 at Time 3.

Data Analysis

Quantitative Analyses

All statistical computations were performed in the open-source R software program [48]. Descriptive statistics were used to describe the sample characteristics, survey scores, and intervention use. Longitudinal spaghetti plots were performed to explore time trends and form. A repeated measures ANOVA was conducted to detect group and within-individual differences during survey time points (Time 1-Time 3). Longitudinal mixed effects models with random effects for time, frequency, or duration were computed to detect changes in stress within individuals. A linear regression model with random effects controlled for participant variations was used to measure change in affect and stress resulting from each VR session.

Several models were run to explore whether dosage (number of sessions and duration of use) moderated the change in momentary stress over time. For dosage models, we explored whether changes in stress scores were linear (uniform rate of improvement as dosage increased), quadratic (declining rate of improvement as dosage increased), or cubic (declining and then increasing rate of improvement as dosage increased).

Full maximum likelihood estimation was used, and model building followed a standard procedure [49]. A null model was built first to establish baseline variance for stress over time, followed by longitudinal trend models testing linear, quadratic, and cubic longitudinal trends. These were run on 3 separate sets of models testing longitudinal trends for variables representing number of days since baseline, number of times the VR was used, and number of minutes the VR was used. The best longitudinal trend was selected by model fit deviance statistics using $-2 \log$ likelihood and Akaike information criterion. We tested for possible moderation effects by computing models with each variable and simple interaction between them. Moderation models included possible moderation between stress over time and (1) frequency x duration, (2) baseline PSS, (3) baseline PHQ-9, and (4) baseline MAAS. Significance for moderator terms was determined by t score significance values for covariate estimates.

Post Hoc Groupings

For the purposes of analysis, participants were grouped into depression level and VR use categories based upon their study data. We based 4 mutually exclusive VR use groupings (minimal [<3 sessions], low use [$3-4$ sessions], moderate use [$5-7$ sessions], high use [≥ 8 sessions]) upon their self-administered VR use during the study. Depression levels were assessed using the Time 1 PHQ-9 scores. Participants were grouped into mild ($\text{PHQ-9} < 5$), moderate ($\text{PHQ-9} = 5-9$), and severe ($\text{PHQ-9} \geq 10$) depression levels. We excluded 8 participants from the analyses exploring the effect of the VR environment on surveyed variables (depression, retrospective stress, mindfulness, cognitive fusion) given their low use of the VR headset (<3 sessions). However, all 44 participants were included in the analyses exploring the relationship between VR use and stress over time.

Qualitative Analyses

As part of our mixed methods design, the qualitative data were gathered concurrently with our quantitative instruments and then explored to help contextualize our quantitative findings. Exit interview data were analyzed using a collaborative thematic analysis protocol. Using raw video data from each of the exit interviews, participant VR session logs, and text messaging, the team of researchers engaged in a collaborative, reflexive thematic analysis [50,51]. Analysis began with the extraction of excerpts that felt salient in relation to our research questions around activity in VR, emotional experience, and the effect of VR on stress. From a review of extracted excerpts, open coding was used to create a categorical code book. With the code book, researchers then revisited the data to further contextualize the categorical codes in an effort to represent the depth and breadth of experiences described by participants. This process was repeated until the research team felt we had sufficient evidence to contextualize our study findings.

Results

Participant Characteristics

A total of 118 individuals accessed the eligibility screening, 100 completed the screening, 94 were eligible, and 51 enrolled. Reasons for ineligibility included age older than 18 years (n=4), age younger than 14 years (n=1), seizure disorder (n=1), and out of the geographic area (n=1). After data collection, 7 participants were removed from those enrolled: 2 participants did not complete baseline surveys; 2 did not use the intervention (8% attrition); and although they completed all study procedures and described using the intervention, we found no headset data for 3 participants. Therefore, because we could not objectively confirm use of the headset, these participants were removed from the study. The final sample included 44 adolescents. See [Multimedia Appendix 2](#) for all participant demographic characteristics.

Participants were aged 14 years to 18 years (mean 15.82 years) and in grades 8 through 12 (mean 10.09). Participants identified their gender as boys (n=17), girls (n=23), and nonbinary or

gender fluid (n=4). Participants completed a total of 1651 (mean 45.86, SD 19.24) momentary reports of their stress level and mood during the 3-week study period. The average response rate for random, within-day reports was 33%, which was expected given the randomized schedule. In addition, participants completed 330 pre- and post-VR session logs reporting their stress and affect before and after headset use as well as their comfort level.

RQ1: How Did Teens Use RESeT and How Did They Rate Its Implementation?

Without prompting or using incentives, teens used RESeT, on average, twice a week (number of sessions: mean 6.29, SD 4.51; range 1-24) over the 21-day study period. The average duration of a VR session was 11.5 (SD 6.47; range 1-45) minutes. No significant differences were found when exploring the effect of gender, age, or depression level on VR use nor did we find that VR use affected cognitive fusion, mindfulness, or retrospective stress. We did create post hoc VR use groupings for comparison in our stress analyses. See [Table 2](#) for VR use groupings.

The average usability rating of the VR system (SUS) was good (mean 74.87, SD 11.61); 37 of the 44 participants (84%) rated the system a 68 or higher, suggesting the standalone headset was fairly easy to use without any external support. The average usability rating (IUS) of RESeT was also good (mean 76.92, SD 11.7); 35 of the 44 participants (80%) rated the intervention a 68 or higher, which suggests the VR environment was also fairly easy to use. Intervention acceptability (mean 15.67, SD 3.7), feasibility (mean 15.9, SD 2.95), and appropriateness (mean 15.23, SD 2.99) were all in the high range, suggesting participants found the RESeT content to be appropriate and acceptable. In their session logs, teens reported the environment was moderately comfortable, but reports ranged across the sample (mean 3.43, SD .992).

When asked about the future of RESeT, teens suggested that the VR environment would be most accessible and useful as a school or public library resource, allowing teens to use it on site or to check out the headset for home use when needed.

Table 2. Virtual reality use groups by gender and depression level.

Use (number of sessions)	Gender, n (%)			Depression level (via PHQ-9 ^a), n (%)		
	Boys (n=17)	Girls (n=23)	Other (n=4)	Mild (<5; n=13)	Moderate (5-9; n=11)	Severe (≥10; n=20)
Minimal (<3; n=8)	2 (5)	5 (11)	1 (2)	1 (2)	2 (5)	5 (11)
Low (3-4; n=8)	4 (9)	3 (7)	1 (2)	3 (7)	5 (11)	0
Medium (5-7; n=15)	6 (14)	7 (16)	2 (5)	5 (11)	1 (2)	9 (20)
High (≥8; n=13)	5 (11)	8 (18)	0	4 (9)	3 (7)	6 (14)

^a PHQ-9: Patient Health Questionnaire 9.

RQ2: What Is the Experience With Using RESeT?

General Experience

In their VR Logs, teens reported a small reduction in negative affect, a slight increase in positive affect, and a significant decrease in momentary stress. See [Table 3](#) for full details.

In general, teens enjoyed their experience with the VR environment. Most reported that they liked the audio and visual design. "RESeT helps you chill out with ambient noises and being able to explore" (P1, boy, 16 years old, text message). Overall, teens who engaged in each of the activities most commonly reported liking the rock stacking activity. The least favorite activity was the painting activity.

I really liked the rock stacking. I thought that was nice because you could move the rocks and you could stack them and other places in the area...And, I was a little disappointed by the painting. [P95, nonbinary, 18 years old, exit interview]

We analyzed text message and exit interview data to understand how participants described their experience with RESeT. As a result, 4 key themes emerged: calm, regulating, forget about everything, and some discomfort. Each of these themes is described in detail in the following sections.

Table 3. Key survey outcomes over the study period.

Survey outcomes	Baseline (n=44), mean (SD)	Postintervention (n=44), mean (SD)	3-week follow-up (n=44), mean (SD)	F statistic (df)	P value
Perceived stress	19.7 (5.7)	18.5 (4.1)	17.4 (7.5)	1.9 (2)	.15
Cognitive fusion	28.5 (7.5)	26.9 (7.3)	24.8 (9.1)	0.4 (2)	.65
Depression	9.0 (4.8)	5.8 (4.4)	6.7 (5.4)	1.0 (2)	.38
Mindfulness/attention	3.9 (0.8)	4.2 (0.5)	4.2 (0.8)	1.2 (2)	.31

Calm

Overall, teen participants in the study felt generally positive about the environment. Teens described the environment as “calming,” “relaxing,” and “stress-relieving.” As one teen described:

Kind of makes you calm as a whole—more calm, more relaxed. [P103, boy, 17 years old, exit interview]

Another teen described the following:

I really...definitely noticed feeling a lot more calm and mindful after being in the environment and I thought it definitely has a positive impact, especially when you are depressed or anxious about something. [P80, boy, 14 years old, exit interview]

Regulating

In exit interviews, teens suggested that the VR environment helped them to regulate their moods when overwhelmed or upset. As one teen described:

Mostly I would use it when I was like really upset. And so it helped a lot there. I kind of looked forward to doing it. It changed the way I felt, like mentally and stuff. [P39, 15 years old, nonbinary, exit interview]

Some teens also described emotional regulation or making space for them to process big feelings as a result of the environment, for example:

It has 100% the ability to lower and kind of simmer any really high feelings of emotion. [P96, boy, 16 years old, exit interview]

Forget About Everything

Some teens described it more as a form of escape and distraction from unwanted thoughts or feelings, such as:

It gives teens a space to relax and calm down and just forget about everything happening in the real world. [P116, boy, 15 years old, exit interview]

Some participants mentioned feelings of escapism through the VR environment and that it was a great, but temporary, distraction from current stressors:

RESeT let us transport into another world and I forgot about the environment I was in. It transferred me to a different location. It felt like I was going on a trip so even though I had my worries in my head it felt good to forget about the physical things around me and be somewhere else. I'm going on a trip for 10-15 minutes and it relaxes me. [P71, girl, 16 years old, exit interview]

Some Discomfort

It is important to note that, for some participants, there was some discomfort with the headset causing some nausea or dizziness (n=8) or eye strain (n=3):

Well, when I first started using it, afterwards it hurt my eyes for a little bit, but then, after a while on my eyes got adjusted to it so didn't hurt anymore. [P25, girl, 14 years old, exit interview]

Nausea was typically associated with locomotion. Some described the arm swing motion as nauseating, whereas for others, teleporting induced nausea. Overall, nausea and eye strain seemed to lessen or fully resolve by adjusting the headset or getting used to using VR.

Two participants mentioned headaches as a result of using VR, particularly regarding the arm swing movement causing nausea. There was also some comparison of the environment with a video game, which may explain participants feeling bored when compared with entertainment expectations for a video game:

When I first started using the VR headset I kept on getting giant headaches and got really dizzy because I wasn't used to how VR feels yet. So at that point if I weren't doing a study I personally wouldn't continue using the headset. [P38, girl, 18 years old, text message]

RQ3: What Effect Does RESeT Use Have on the Surveyed Measurement of Retrospective Stress (PSS), Depression (PHQ-9), Cognitive Fusion (CFQ), or Mindfulness (MAAS)?

An analysis of surveyed outcomes demonstrated no significant effect of using the VR environment on retrospective stress (PSS), depression (PHQ-9), cognitive fusion (CFQ), or mindfulness (MAAS) for participants regardless of the amount

of VR use. See [Table 3](#) for details. However, we did see significant changes in momentary stress and affect, as described in the following sections.

RQ4: What Effect Does RESeT Use Have on Momentary Stress and Mood?

When exploring the pre- and post-headset session surveys, teens reported a significant reduction in negative affect, a significant

increase in positive affect, and a significant reduction in momentary stress. See [Table 4](#) for full details.

Mixed effects models of change in momentary stress over the 21-day study period found that a linear time model was a better fit than quadratic and cubic models. Stress decreased by 0.328 points per day over the study ($SE=0.12$, $P=.008$).

Table 4. Effect of virtual reality (VR) sessions on momentary affect and stress (n=44; 330 reports).

Affect and stress	Before, mean (SD)	After, mean (SD)	Estimates (relative to “before” survey)	P value
Negative affect	9.2 (3.6)	6.9 (2.4)	-2.3	.001
Positive affect	10.8 (4.0)	12.0 (4.1)	1.3	.001
Momentary stress	37.9 (27.1)	24.0 (20.6)	-13.3	.001

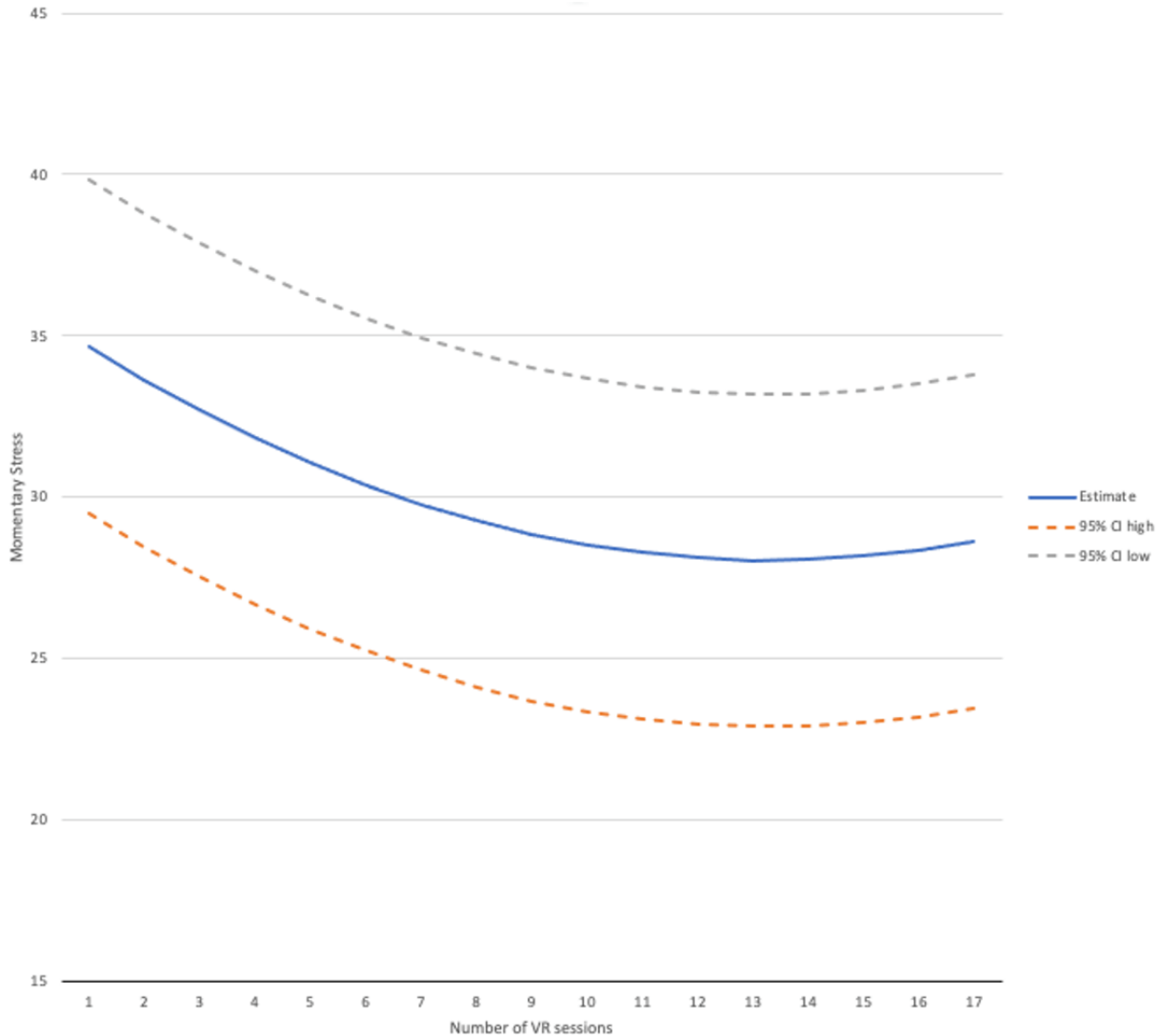
RQ4a: Do Baseline Depression, Mindfulness, and Stress Moderate Momentary Stress Over the 3-Week Intervention?

The rate of decrease in momentary stress score was not significantly moderated by baseline scores of retrospective stress (PSS: interaction=-0.021, $SE=0.021$, $P=.31$), depression (PHQ-9: interaction=-0.04, $SE=0.03$, $P=.14$), or mindfulness (MAAS: interaction=0.14, $SE=0.16$, $P=.38$).

RQ4b: Does Dosage (Frequency and Duration of VR Use) Moderate Momentary Stress Over the 3-Week Intervention?

The best-fitting mixed effects model for frequency of use included both linear and quadratic use frequency, indicating

that there was a stronger association with improved stress scores during the first several uses (linear frequency=-1.08, $SE=0.50$, $P=.03$), which decreased as frequency of use increased (quadratic frequency=0.043, $SE=0.02$, $P=.03$; see [Figure 3](#)). The best-fitting model for cumulative duration of use was linear, though the individual parameter for duration was not significant (linear minutes=0.01, $SE=0.003$, $P=.07$). A model exploring a possible interaction effect of frequency by duration on stress did not find significant effects (frequency x duration=0.001, $SE=0.001$, $P=.61$). See [Figure 3](#) for an illustration.

Figure 3. Predicted change in the stress score, with the 95% CI, by number of uses of the virtual reality (VR) headset over the 3-week period.

Discussion

Principal Findings

It was evident from this study that the VR environment was desirable and a usable system within a self-administered, autonomous home setting. In addition, teens chose to use RESeT repeatedly of their own volition despite its limited interactions. As with our previous studies [28,32], teens confirmed their desire and enjoyment of nature in VR as a stress-reducing environment.

Although RESeT did not significantly affect repeated survey measurements of depression, mindfulness, nor cognitive fusion, it did decrease momentary stress and positively affect momentary mood. This reduction in stress was correlated with the frequency of use, suggesting that self-administered VR environments may be effective to reduce momentary stress. However, the benefit from increased frequency of use tapered off with high use, suggesting that there may be a limit to the impact of RESeT over time. Counterintuitively, although frequency of use was associated with further stress reduction, duration of use was not, suggesting that longer sessions may not be more beneficial. Also likely, it could be that participants

self-regulated their use and ended a session once they felt a reduction in stress, such that long sessions and short sessions had a relatively equal impact.

Comparison With Prior Work

It was not surprising that more stable factors such as depression, cognitive fusion, and mindfulness were not significantly changed by this short-term, self-administered intervention. However, our exit interviews with teens provided strong evidence that, for some teens, the RESeT VR environment provided a place for relaxation as well as emotional regulation. Bond et al [52] found that VR allowed for “safe space to practice” interactions for adults with agoraphobia. It is feasible that VR can also provide a safe space to process big emotions for teens. Although we hoped to see significant changes in cognitive fusion given one exercise (the boat launch) was designed specifically for this purpose, teens did describe experiences of emotional regulation. Computer games have shown significant improvements in emotional regulation in adults [53], and a preliminary study found VR could both improve and measure emotional regulation in adolescents [54]. For this reason, measuring emotional regulation as a result of VR nature environment experiences may be an important factor to consider.

Previously, we conducted a 2-week study exploring a high-fidelity, commercial VR nature-based environment [19]. In the 2-week study, momentary stress was also significantly reduced, suggesting that these types of environments may be effective to reduce momentary stress. In the 2-week study, we also found participants averaged about 6 VR sessions over the study period. This suggests that, perhaps in these self-administered environments, engagement or effect may taper around 6 sessions. Interestingly, similar themes of relaxation and escape emerged from the participants' responses to the VR environment. Granted, both studies explored nature settings, but combined findings suggest teens find nature relaxing and that VR offers an opportunity to escape real-world stressors. Future design research is needed to explore further translation of evidence-based CBT, dialectical behavioral therapy, and acceptance and commitment therapy exercises into immersive VR activities in an effort to understand what types of activities are most engaging and effective.

Limitations and Next Steps

This study was an exploratory usability study of self-administered VR and therefore does not constitute a more rigorous clinical trial. In addition, this study was limited in several ways. First, to establish the effectiveness of RESeT, a control or comparison group, possibly using a well-crafted placebo VR experience, would be necessary. Second, this study was limited in the diversity of its sample (broad range of depression levels) as well as participants' self-selection and ability to self-administer the VR tool. Although each of these factors provides some real-world context about how VR may be used by teens of varying levels of depression, it also limits any generalizability of these data to other samples. Third, the study also lacks controlled data or comparison data to determine the true effect of VR on the measured variables. Fourth, the

participant-level sample size was modest and lacked statistical power to detect small to moderate effects; findings should be viewed as preliminary, consistent with the scope of an exploratory study. Finally, given the probable novelty of VR and short intervention period, teen participants likely experienced a novelty effect, and engagement may have tapered during a longer intervention period.

Further research could explore the VR headset as a community-based tool, such as in a school or library setting, to increase access for teens. VR technology has been found an engaging tool in public library settings [55], which has prompted some public libraries to launch programs to support mental health [56]. As per Kelly et al [57], we included minimal interactions, hoping not to distract participants from mindfulness. However, teens wanted more engagement and interaction; therefore, future evidence-based mental health VR interventions could explore more engaging and interactive activities, as it is likely with a larger platform, more choices, and a more diverse set of activities, teens would be more engaged with the VR platform.

Conclusion

Teens enjoyed and repeatedly used our VR environment, which included 6 evidence-based activities in an open world nature environment, without further incentive. They found the VR system and the RESeT usable, and many reported feeling relaxed or calm as a result. We found that stress decreased over time and that increased VR session frequency further decreased momentary stress. However, we also learned that increased session duration did not improve stress outcomes, suggesting that even brief VR sessions can be effective. These findings indicate that VR is a feasible and likely attractive platform for evidence-based mental health interventions.

Acknowledgments

We would like to acknowledge the many teens who, despite the COVID-19 pandemic, agreed to work with us. The data from teens during the design and development and, importantly, the testing of the Relaxation Environment for Stress in Teens (RESeT) were essential to creating a usable tool. We also greatly appreciate the development work for this project led by Nora Carr, Jared Canright, and Todd Little. We also acknowledge the teen-preferred background music for RESeT, which was created by nstruction.co.

This project was supported by the University of Washington ALACRITY Center (National Institutes of Health (NIH)/National Institutes of Mental Health (NIMH) P50MN115h37; principal investigator [PI] Arean). Study data were collected and managed using Research Electronic Data Capture (REDCap) tools hosted at the Institute of Translational Health Sciences, supported by NIH/National Center for Advancing Translational Sciences (NCATS) UL1TR002319. The study sponsors did not play any role in the study design, conduct or analysis and interpretation of data, or writing of this report. Information or content and conclusions are those of the authors and should not be construed as the official position or policy of the study sponsors nor should any endorsements be inferred.

Data Availability

Study data are available upon request.

Authors' Contributions

EAB was the primary investigator who conceptualized the study; oversaw all study procedures, data collection, and data analyses; and led authorship of this manuscript. JS was co-principal investigator of the study; monitored all study procedures, including data collection and management; and shared senior authorship with EAB. SR and SHM helped to conduct and manage the study,

began preliminary analyses, and helped with authoring the paper. HZ and MDP conducted the analyses and authored the analysis section.

Conflicts of Interest

None declared.

Multimedia Appendix 1

RESeT VR Environment Demonstration.

[[MP4 File \(MP4 Video\), 129744 KB - xr_v1i1e49171_app1.mp4](#)]

Multimedia Appendix 2

Participant Demographics.

[[DOCX File , 15 KB - xr_v1i1e49171_app2.docx](#)]

References

1. Stress in America - Generation Z. American Psychological Association. 2018 Oct. URL: <https://www.apa.org/news/press/releases/stress/2018/stress-gen-z.pdf> [accessed 2024-03-30]
2. Twenge JM, Cooper AB, Joiner TE, Duffy ME, Binau SG. Age, period, and cohort trends in mood disorder indicators and suicide-related outcomes in a nationally representative dataset, 2005-2017. *J Abnorm Psychol* 2019 Apr;128(3):185-199. [doi: [10.1037/abn0000410](https://doi.org/10.1037/abn0000410)] [Medline: [30869927](https://pubmed.ncbi.nlm.nih.gov/30869927/)]
3. Walter HJ, Bukstein OG, Abright AR, Keable H, Ramtekkar U, Ripperger-Suhler J, et al. Clinical Practice Guideline for the Assessment and Treatment of Children and Adolescents With Anxiety Disorders. *J Am Acad Child Adolesc Psychiatry* 2020 Oct;59(10):1107-1124. [doi: [10.1016/j.jaac.2020.05.005](https://doi.org/10.1016/j.jaac.2020.05.005)] [Medline: [32439401](https://pubmed.ncbi.nlm.nih.gov/32439401/)]
4. Major Depression. National Institute of Mental Health. URL: <http://www.nimh.nih.gov/health/statistics/major-depression.shtml> [accessed 2024-03-30]
5. Wyman PA. Developmental approach to prevent adolescent suicides: research pathways to effective upstream preventive interventions. *Am J Prev Med* 2014 Sep;47(3 Suppl 2):S251-S256 [FREE Full text] [doi: [10.1016/j.amepre.2014.05.039](https://doi.org/10.1016/j.amepre.2014.05.039)] [Medline: [25145747](https://pubmed.ncbi.nlm.nih.gov/25145747/)]
6. MacDonald K, Fainman-Adelman N, Anderson KK, Iyer SN. Pathways to mental health services for young people: a systematic review. *Soc Psychiatry Psychiatr Epidemiol* 2018 Oct;53(10):1005-1038 [FREE Full text] [doi: [10.1007/s00127-018-1578-y](https://doi.org/10.1007/s00127-018-1578-y)] [Medline: [30136192](https://pubmed.ncbi.nlm.nih.gov/30136192/)]
7. Dewhurst A, Laugharne R, Shankar R. Therapeutic use of serious games in mental health: scoping review. *BJPsych Open* 2022 Mar 02;8(2):e37 [FREE Full text] [doi: [10.1192/bjo.2022.4](https://doi.org/10.1192/bjo.2022.4)] [Medline: [35105418](https://pubmed.ncbi.nlm.nih.gov/35105418/)]
8. Fleming TM, Bavin L, Stasiak K, Hermansson-Webb E, Merry SN, Cheek C, et al. Serious games and gamification for mental health: current status and promising directions. *Front Psychiatry* 2016;7:215 [FREE Full text] [doi: [10.3389/fpsy.2016.00215](https://doi.org/10.3389/fpsy.2016.00215)] [Medline: [28119636](https://pubmed.ncbi.nlm.nih.gov/28119636/)]
9. Hollis C, Falconer CJ, Martin JL, Whittington C, Stockton S, Glazebrook C, et al. Annual Research Review: Digital health interventions for children and young people with mental health problems - a systematic and meta-review. *J Child Psychol Psychiatry* 2017 Apr;58(4):474-503. [doi: [10.1111/jcpp.12663](https://doi.org/10.1111/jcpp.12663)] [Medline: [27943285](https://pubmed.ncbi.nlm.nih.gov/27943285/)]
10. Deng W, Hu D, Xu S, Liu X, Zhao J, Chen Q, et al. The efficacy of virtual reality exposure therapy for PTSD symptoms: A systematic review and meta-analysis. *J Affect Disord* 2019 Oct 01;257:698-709. [doi: [10.1016/j.jad.2019.07.086](https://doi.org/10.1016/j.jad.2019.07.086)] [Medline: [31382122](https://pubmed.ncbi.nlm.nih.gov/31382122/)]
11. Donker T, Cornelisz I, van Klaveren C, van Straten A, Carlbring P, Cuijpers P, et al. Effectiveness of self-guided app-based virtual reality cognitive behavior therapy for acrophobia: a randomized clinical trial. *JAMA Psychiatry* 2019 Jul 01;76(7):682-690 [FREE Full text] [doi: [10.1001/jamapsychiatry.2019.0219](https://doi.org/10.1001/jamapsychiatry.2019.0219)] [Medline: [30892564](https://pubmed.ncbi.nlm.nih.gov/30892564/)]
12. Pallavicini F, Argenton L, Toniazzi N, Aceti L, Mantovani F. Virtual reality applications for stress management training in the military. *Aerosp Med Hum Perform* 2016 Dec 01;87(12):1021-1030. [doi: [10.3357/AMHP.4596.2016](https://doi.org/10.3357/AMHP.4596.2016)] [Medline: [28323588](https://pubmed.ncbi.nlm.nih.gov/28323588/)]
13. Schleider JL, Mullarkey MC, Weisz JR. Virtual reality and web-based growth mindset interventions for adolescent depression: protocol for a three-arm randomized trial. *JMIR Res Protoc* 2019 Jul 09;8(7):e13368 [FREE Full text] [doi: [10.2196/13368](https://doi.org/10.2196/13368)] [Medline: [31290406](https://pubmed.ncbi.nlm.nih.gov/31290406/)]
14. Halldorsson B, Hill C, Waite P, Partridge K, Freeman D, Creswell C. Annual Research Review: Immersive virtual reality and digital applied gaming interventions for the treatment of mental health problems in children and young people: the need for rigorous treatment development and clinical evaluation. *J Child Psychol Psychiatry* 2021 May 02;62(5):584-605. [doi: [10.1111/jcpp.13400](https://doi.org/10.1111/jcpp.13400)] [Medline: [33655534](https://pubmed.ncbi.nlm.nih.gov/33655534/)]
15. Jeffs D, Dorman D, Brown S, Files A, Graves T, Kirk E, et al. Effect of virtual reality on adolescent pain during burn wound care. *J Burn Care Res* 2014;35(5):395-408. [doi: [10.1097/BCR.000000000000019](https://doi.org/10.1097/BCR.000000000000019)] [Medline: [24823326](https://pubmed.ncbi.nlm.nih.gov/24823326/)]

16. Walther-Larsen S, Petersen T, Friis SM, Aagaard G, Drivenes B, Opstrup P. Immersive virtual reality for pediatric procedural pain: a randomized clinical trial. *Hosp Pediatr* 2019 Jul;9(7):501-507. [doi: [10.1542/hpeds.2018-0249](https://doi.org/10.1542/hpeds.2018-0249)] [Medline: [31160472](https://pubmed.ncbi.nlm.nih.gov/31160472/)]
17. Shiri S, Feintuch U, Weiss N, Pustilnik A, Geffen T, Kay B, et al. A virtual reality system combined with biofeedback for treating pediatric chronic headache--a pilot study. *Pain Med* 2013 May;14(5):621-627. [doi: [10.1111/pme.12083](https://doi.org/10.1111/pme.12083)] [Medline: [23659372](https://pubmed.ncbi.nlm.nih.gov/23659372/)]
18. Kahlon S, Lindner P, Nordgreen T. Virtual reality exposure therapy for adolescents with fear of public speaking: a non-randomized feasibility and pilot study. *Child Adolesc Psychiatry Ment Health* 2019;13:47 [FREE Full text] [doi: [10.1186/s13034-019-0307-y](https://doi.org/10.1186/s13034-019-0307-y)] [Medline: [31890004](https://pubmed.ncbi.nlm.nih.gov/31890004/)]
19. Björling EA, Sonney J, Rodriguez S, Carr N, Zade H, Moon SH. Exploring the effect of a nature-based virtual reality environment on stress in adolescents. *Front. Virtual Real* 2022 Apr 8;3:1. [doi: [10.3389/frvir.2022.831026](https://doi.org/10.3389/frvir.2022.831026)]
20. Lindner P, Hamilton W, Miloff A, Carlbring P. How to treat depression with low-intensity virtual reality interventions: perspectives on translating cognitive behavioral techniques into the virtual reality modality and how to make anti-depressive use of virtual reality-unique experiences. *Front Psychiatry* 2019;10:792 [FREE Full text] [doi: [10.3389/fpsy.2019.00792](https://doi.org/10.3389/fpsy.2019.00792)] [Medline: [31736809](https://pubmed.ncbi.nlm.nih.gov/31736809/)]
21. Abd-Alrazaq A, Alajlani M, Alhuwail D, Schneider J, Akhu-Zaheya L, Ahmed A, et al. The effectiveness of serious games in alleviating anxiety: systematic review and meta-analysis. *JMIR Serious Games* 2022 Mar 14;10(1):e29137 [FREE Full text] [doi: [10.2196/29137](https://doi.org/10.2196/29137)] [Medline: [35156932](https://pubmed.ncbi.nlm.nih.gov/35156932/)]
22. Ahmadpour N, Keep M, Janssen A, Rouf AS, Marthick M. Design strategies for virtual reality interventions for managing pain and anxiety in children and adolescents: scoping review. *JMIR Serious Games* 2020 Jan 31;8(1):e14565 [FREE Full text] [doi: [10.2196/14565](https://doi.org/10.2196/14565)] [Medline: [32012042](https://pubmed.ncbi.nlm.nih.gov/32012042/)]
23. Spinuzzi C. The methodology of participatory design. *Technical Communication* 2005;52(2):163-174 page xi [FREE Full text]
24. Schuler D, Namioka A. Participatory design: Principles and practices. Boca Raton, FL: CRC Press; 1993.
25. Steen M. Tensions in human-centred design. *CoDesign* 2011 Mar;7(1):45-60. [doi: [10.1080/15710882.2011.563314](https://doi.org/10.1080/15710882.2011.563314)]
26. Bell A, Davis K. Learning through Participatory Design: Designing Digital Badges for and with Teens. 2016 Presented at: 15th International Conference on Interaction Design and Children; June 21-24, 2016; Manchester, United Kingdom. [doi: [10.1145/2930674.2930705](https://doi.org/10.1145/2930674.2930705)]
27. Thorn P, Hill NT, Lamblin M, Teh Z, Battersby-Coulter R, Rice S, et al. Developing a suicide prevention social media campaign with young people (The #Chatsafe Project): co-design approach. *JMIR Ment Health* 2020 May 11;7(5):e17520 [FREE Full text] [doi: [10.2196/17520](https://doi.org/10.2196/17520)] [Medline: [32391800](https://pubmed.ncbi.nlm.nih.gov/32391800/)]
28. Björling EA, Rose E, Ren R. Teen-Robot Interaction: A Pilot Study of Engagement with a Low-fidelity Prototype. 2018 Presented at: HRI '18: ACM/IEEE International Conference on Human-Robot; March 5-8, 2018; Chicago, IL. [doi: [10.1145/3173386.3177068](https://doi.org/10.1145/3173386.3177068)]
29. Fitton D, Bell BT, Little L, Horton M, Read JC, Rouse M, et al. Working with Teenagers in HCI Research: A Reflection on Techniques Used in the Taking on the Teenagers Project. In: Little L, Fitton D, Bell B, Toth N, editors. *Perspectives on HCI Research with Teenagers*. Cham, Switzerland: Springer; 2016:237-267.
30. Fisher KE, Bishop AP, Magassa L, Fawcett P. Action!: codesigning interactive technology with immigrant teens. 2014 Presented at: IDC'14: Interaction Design and Children 2014; June 17-20, 2014; Aarhus, Denmark p. 345. [doi: [10.1145/2593968.2610488](https://doi.org/10.1145/2593968.2610488)]
31. Realpe A, Elahi F, Bucci S, Birchwood M, Vlaev I, Taylor D, et al. Co-designing a virtual world with young people to deliver social cognition therapy in early psychosis. *Early Interv Psychiatry* 2020 Mar 25;14(1):37-43. [doi: [10.1111/eip.12804](https://doi.org/10.1111/eip.12804)] [Medline: [30908854](https://pubmed.ncbi.nlm.nih.gov/30908854/)]
32. Björling EA, Cicero R, Sankar A, Sekar A. Thought Disposal: Co-Designing a virtual interaction to reduce stress in teens. 2019 Presented at: IDC '19: Interaction Design and Children; June 12-15, 2019; Boise, ID. [doi: [10.1145/3311927.3325313](https://doi.org/10.1145/3311927.3325313)]
33. McCauley E, Berk MS, Asarnow JR, Adrian M, Cohen J, Korslund K, et al. Efficacy of dialectical behavior therapy for adolescents at high risk for suicide: a randomized clinical trial. *JAMA Psychiatry* 2018 Aug 01;75(8):777-785 [FREE Full text] [doi: [10.1001/jamapsychiatry.2018.1109](https://doi.org/10.1001/jamapsychiatry.2018.1109)] [Medline: [29926087](https://pubmed.ncbi.nlm.nih.gov/29926087/)]
34. Livheim F, Hayes L, Ghaderi A, Magnusdottir T, Högfeldt A, Rowse J, et al. The Effectiveness of Acceptance and Commitment Therapy for Adolescent Mental Health: Swedish and Australian Pilot Outcomes. *J Child Fam Stud* 2014 Feb 7;24(4):1016-1030. [doi: [10.1007/s10826-014-9912-9](https://doi.org/10.1007/s10826-014-9912-9)]
35. Díaz-González MC, Pérez Dueñas C, Sánchez-Raya A, Moriana Elvira JA, Sánchez Vázquez V. Mindfulness-based stress reduction in adolescents with mental disorders: A randomised clinical trial. *Psicothema* 2018 May;30(2):165-170. [doi: [10.7334/psicothema2017.259](https://doi.org/10.7334/psicothema2017.259)] [Medline: [29694316](https://pubmed.ncbi.nlm.nih.gov/29694316/)]
36. Assaz DA, Roche B, Kanter JW, Oshiro CKB. Cognitive defusion in acceptance and commitment therapy: what are the basic processes of change? *Psychol Rec* 2018 May 22;68(4):405-418. [doi: [10.1007/s40732-017-0254-z](https://doi.org/10.1007/s40732-017-0254-z)]
37. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009 Apr;42(2):377-381 [FREE Full text] [doi: [10.1016/j.jbi.2008.08.010](https://doi.org/10.1016/j.jbi.2008.08.010)] [Medline: [18929686](https://pubmed.ncbi.nlm.nih.gov/18929686/)]

38. Sonney J, Björling EA, Rodriguez S, Carr N. Pivoting to "no contact": a protocol for conducting a virtual reality relaxation home study for teens amidst the COVID-19 pandemic. *J Pediatr Health Care* 2021;35(5):552-558 [FREE Full text] [doi: [10.1016/j.pedhc.2021.01.002](https://doi.org/10.1016/j.pedhc.2021.01.002)] [Medline: [33773861](https://pubmed.ncbi.nlm.nih.gov/33773861/)]
39. Weiner BJ, Lewis CC, Stanick C, Powell BJ, Dorsey CN, Clary AS, et al. Psychometric assessment of three newly developed implementation outcome measures. *Implement Sci* 2017 Aug 29;12(1):108 [FREE Full text] [doi: [10.1186/s13012-017-0635-3](https://doi.org/10.1186/s13012-017-0635-3)] [Medline: [28851459](https://pubmed.ncbi.nlm.nih.gov/28851459/)]
40. Bangor A, Kortum PT, Miller JT. An empirical evaluation of the System Usability Scale. *International Journal of Human-Computer Interaction* 2008 Jul 30;24(6):574-594. [doi: [10.1080/10447310802205776](https://doi.org/10.1080/10447310802205776)]
41. Lyon AR, Pullmann MD, Jacobson J, Osterhage K, Achkar MA, Renn BN, et al. Assessing the usability of complex psychosocial interventions: the Intervention Usability Scale. *Implement Res Pract* 2021 Feb 08;2:263348952098782 [FREE Full text] [doi: [10.1177/2633489520987828](https://doi.org/10.1177/2633489520987828)] [Medline: [35601889](https://pubmed.ncbi.nlm.nih.gov/35601889/)]
42. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med* 2001 Sep;16(9):606-613 [FREE Full text] [doi: [10.1046/j.1525-1497.2001.016009606.x](https://doi.org/10.1046/j.1525-1497.2001.016009606.x)] [Medline: [11556941](https://pubmed.ncbi.nlm.nih.gov/11556941/)]
43. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. *J Health Soc Behav* 1983 Dec;24(4):385-396. [Medline: [6668417](https://pubmed.ncbi.nlm.nih.gov/6668417/)]
44. Gillanders DT, Bolderston H, Bond FW, Dempster M, Flaxman PE, Campbell L, et al. The development and initial validation of the cognitive fusion questionnaire. *Behav Ther* 2014 Jan;45(1):83-101 [FREE Full text] [doi: [10.1016/j.beth.2013.09.001](https://doi.org/10.1016/j.beth.2013.09.001)] [Medline: [24411117](https://pubmed.ncbi.nlm.nih.gov/24411117/)]
45. Osman A, Lamis DA, Bagge CL, Freedenthal S, Barnes SM. The Mindful Attention Awareness Scale: further examination of dimensionality, reliability, and concurrent validity estimates. *J Pers Assess* 2016;98(2):189-199. [doi: [10.1080/00223891.2015.1095761](https://doi.org/10.1080/00223891.2015.1095761)] [Medline: [26560259](https://pubmed.ncbi.nlm.nih.gov/26560259/)]
46. About SEMA. SEMA3. URL: <https://sema3.com/about.html> [accessed 2024-03-30]
47. Watson D, Clark LA, Tellegen A. Development and validation of brief measures of positive and negative affect: the PANAS scales. *J Pers Soc Psychol* 1988 Jun;54(6):1063-1070. [doi: [10.1037//0022-3514.54.6.1063](https://doi.org/10.1037//0022-3514.54.6.1063)] [Medline: [3397865](https://pubmed.ncbi.nlm.nih.gov/3397865/)]
48. R Core Team. R: A language and environment for statistical ## computing. Vienna, Austria: R Foundation for Statistical Computing; 2021. URL: <https://www.R-project.org/> [accessed 2024-03-30]
49. Singer JD, Willett JB. Applied longitudinal data analysis: Modeling change and event occurrence. New York, NY: Oxford University Press; 2003.
50. Braun V, Clarke V. Conceptual and design thinking for thematic analysis. *Qualitative Psychology* 2022 Feb;9(1):3-26. [doi: [10.1037/qup0000196](https://doi.org/10.1037/qup0000196)]
51. Braun V, Clarke V. Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health* 2019 Jun 13;11(4):589-597. [doi: [10.1080/2159676x.2019.1628806](https://doi.org/10.1080/2159676x.2019.1628806)]
52. Bond J, Kenny A, Pinfold V, Couperthwaite L, gameChange Lived Experience Advisory Panel, Kabir T, et al. A safe place to learn: peer research qualitative investigation of gameChange virtual reality therapy. *JMIR Serious Games* 2023 Jan 16;11:e38065 [FREE Full text] [doi: [10.2196/38065](https://doi.org/10.2196/38065)] [Medline: [36645707](https://pubmed.ncbi.nlm.nih.gov/36645707/)]
53. Mena-Moreno T, Fernández-Aranda F, Granero R, Munguía L, Steward T, López-González H, et al. A serious game to improve emotion regulation in treatment-seeking individuals with gambling disorder: a usability study. *Front Psychol* 2021;12:621953 [FREE Full text] [doi: [10.3389/fpsyg.2021.621953](https://doi.org/10.3389/fpsyg.2021.621953)] [Medline: [33746839](https://pubmed.ncbi.nlm.nih.gov/33746839/)]
54. Rodríguez A, Rey B, Vara MD, Wrzesien M, Alcañiz M, Baños RM, et al. A VR-based serious game for studying emotional regulation in adolescents. *IEEE Comput. Grap. Appl* 2015 Jan;35(1):65-73. [doi: [10.1109/mcg.2015.8](https://doi.org/10.1109/mcg.2015.8)]
55. Dahya N, Lee JH, Lee KJ, King WE, Goel M, Yassin H. Virtual reality in public libraries. University of Washington Information School. 2019. URL: https://digitalyouth.ischool.uw.edu/sites/digitalyouth.ischool.uw.edu/files/virtual_reality_in_public_libraries.pdf [accessed 2024-03-30]
56. Stringer H. Libraries as mental health hubs. *Monitor on Psychology* 2020 Apr 01;51(3):26 [FREE Full text]
57. Kelly RM, Seabrook EM, Foley F, Thomas N, Nedeljkovic M, Wadley G. Design considerations for supporting mindfulness in virtual reality. *Front. Virtual Real* 2022 Jan 21;2:1. [doi: [10.3389/frvir.2021.672556](https://doi.org/10.3389/frvir.2021.672556)]

Abbreviations

- CBT:** cognitive behavioral theory
- CFQ:** Cognitive Fusion Questionnaire
- IUS:** Intervention Usability Questionnaire
- MAAS:** Mindfulness Attention and Awareness Scale
- PD:** participatory design
- PHQ-9:** Patient Health Questionnaire 9
- PSS:** Perceived Stress Scale
- REDCap:** Research Electronic Data Capture
- RESeT:** Relaxation Environment for Stress in Teens
- RQ:** research question

SG: serious game

SUS: System Usability Scale

VR: virtual reality

Edited by T Leung; submitted 22.05.23; peer-reviewed by K Steinbeck, T Cahill; comments to author 08.10.23; revised version received 07.11.23; accepted 19.03.24; published 22.04.24.

Please cite as:

Björling EA, Sonney J, Zade H, Rodriguez S, Pullmann MD, Moon SH

Using Virtual Reality to Reduce Stress in Adolescents: Mixed Methods Usability Study

JMIR XR Spatial Comput 2024;1:e49171

URL: <https://xr.jmir.org/2024/1/e49171>

doi: [10.2196/49171](https://doi.org/10.2196/49171)

PMID:

©Elin A Björling, Jennifer Sonney, Himanshu Zade, Sofia Rodriguez, Michael D Pullmann, Soo Hyun Moon. Originally published in JMIR XR and Spatial Computing (<https://xr.jmir.org>), 22.04.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR XR and Spatial Computing, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Original Paper

Use of Immersive Virtual Reality in Nursing Homes for People With Dementia: Feasibility Study to Assess Cognitive, Motor, and Emotional Responses

Alexander Prinz¹, MSc; Dan Buerger¹, MSc; Jelena Krafft², MSc; Matteo Bergmann², MSc; Alexander Woll², Prof Dr; Bettina Barisch-Fritz^{2*}, PhD; Kerstin Witte^{1*}, Prof Dr

¹Department of Sports Engineering/Movement Science, Otto-von-Guericke-University Magdeburg, Magdeburg, Germany

²Institute of Sports and Sports Science, Karlsruhe Institute of Technology, Karlsruhe, Germany

*these authors contributed equally

Corresponding Author:

Bettina Barisch-Fritz, PhD

Institute of Sports and Sports Science

Karlsruhe Institute of Technology

Engler-Bunte-Ring 15

Karlsruhe, 76131

Germany

Phone: 49 721 49049244

Email: bettina.barisch-fritz@kit.edu

Abstract

Background: Physical activity interventions for people with dementia have shown promising effects in improving cognition and physical function or slowing disease-related decline. Immersive virtual reality (iVR), using head-mounted displays, facilitates realistic experiences by blurring the boundaries between VR and the real world. The use of iVR for people with dementia offers the potential to increase active time and improve dementia therapy and care through exercise interventions. However, the feasibility of using VR use in people with dementia, considering changes in motor, cognitive, psychological, and physiological parameters, remains insufficiently investigated.

Objective: This study aims to investigate the feasibility of using iVR in people with dementia or mild cognitive impairment in nursing homes. Specifically, we examined changes in motor performance (balance and mobility), cognitive performance (global cognition and executive functions), emotional responses, and fear of falling using iVR.

Methods: Utilizing a pre-post design, this study recruited 35 participants with mild-to-moderate dementia, assessed by the Mini-Mental State Examination (MMSE). Participants underwent a single session involving iVR exposure, with pre- and postexposure assessments and a feedback form, to exclude negative effects on cognitive and motor functions, mood, anxiety levels, and balance performance. The use of iVR involved 4 scenes, with a total length of 8 minutes. These scenes depicted a park with short and rather passive impressions presented as a 360° video in a head-mounted display. Before and after using the iVR, cognitive parameters were assessed using the Trail-Making Test A (TMT-A), motor parameters were assessed using the FICSIT-4 (Frailty and Injuries: Cooperative Studies of Intervention Techniques-4) and Timed-Up-and-Go (TUG) tests, and psychological parameters were assessed using the Dementia Mood Picture Test, State-Trait Anxiety Inventory, and Short Falls Efficacy Scale-International (Short FES-I). The Emotion Rating Scale and the duration of use were recorded during use, and a feedback questionnaire was completed afterward in addition to the posttests. Paired *t* tests and Wilcoxon tests were used to examine pre-post differences.

Results: Of the 35 initial participants, 33 completed the study, which corresponds to a dropout rate of 6%. All 33 participants, who had a mean of 83.71 (SD 5.01) years, had dementia. They showed no statistically significant difference in cognitive and motor performance before and after iVR use. Thus, no negative effects on cognitive and motor functions, mood, anxiety levels, and balance performance were observed. The emotion rating scale also showed that 72% (n=24) felt joy and fun during iVR use, 100% (n=33) showed no emotions such as fear, sadness, or anger, and 93% (n=31) were attentive during iVR use.

Conclusions: The feasibility of using iVR for people with dementia can be rated positively. There were no changes in motor, cognitive, or emotional parameters that would increase the risk of falls or other negative emotional reactions during or after iVR

use. Further studies are needed to investigate prolonged use in a more stimulating computer-generated environment and possible physical and cognitive tasks for people with dementia in nursing homes.

Trial Registration: German Clinical Trials Register DRKS00030616; <https://drks.de/search/de/trial/DRKS00030616>

(*JMIR XR Spatial Comput* 2024;1:e54724) doi:[10.2196/54724](https://doi.org/10.2196/54724)

KEYWORDS

persons with dementia; virtual reality; VR; immersive virtual reality; iVR; head-mounted display; HMD; physical performance; physical activity; physical function; motor performance; Alzheimer's disease; Alzheimer's; Alzheimer's treatment; Alzheimer's care; Alzheimer's symptom control; dementia; dementia therapy; dementia care; cognitive decline; cognitive impairment; cognitive impairments; neurocognition; neurology; neurologist; neurologists; nursing home; nursing homes; nursing facility; senior home; long-term care center; long-term care facility

Introduction

The number of people with dementia is expected to increase to over 152 million worldwide by 2050 [1], representing a high societal burden in terms of costs and care [2]. Dementia treatment is predominantly based on symptom reduction, with drug therapy often being associated with negative side effects [3], making treatment with nonpharmacological interventions important [4]. In particular, physical activity interventions have shown promising effects in improving cognition and physical function or slowing disease-related decline among people with dementia [5-9]. Additionally, quality of life and the ability to perform activities of daily living can also be positively affected by physical activity [7,10,11]. With the increasing use and dissemination of digital health applications in the past, there are new opportunities to complement or improve dementia care (ie, to respond to the individual needs of people with dementia) [12]. Virtual reality (VR) is a possibility that has great potential for treating cognitive impairment in the nursing home setting.

VR is based on computer simulations that allow individuals to enter an artificial environment. A distinction is made between nonimmersive, semi-immersive, and immersive VR technologies. Nonimmersive methods are based on desktop systems, with stereoscopic displays and head tracking, while semi-immersive methods are based on large single-screen or tabletop displays [13]. Immersive VR (iVR) technologies refer to the specification of the hardware (eg, the field of view, screen resolution, and refresh rate), as well as the degree of interaction and how isolated the user is from the outside world [14]. Clay et al [15] define iVR as “systems that encompass the user's field of view and where virtual motion replicates actual head or body motion.” For this purpose, head-mounted displays (HMDs) are usually used to create an even better 3D perspective to completely block out the real environment. Consequently, the immersive method leads to the most authentic experiences [16] and is therefore of particular interest.

VR has already been used in studies to improve cognitive function in both healthy individuals [17] and those with cognitive impairment [18] and to promote well-being in people with dementia [19]. The conclusion of a systematic review and meta-analysis review on the effects of VR-based task-oriented training on people with dementia or mild cognitive impairment (MCI) is that VR interventions are promising nonpharmacological approaches for improving cognitive and motor function [20]. Despite promising intervention effects

[21-23], the feasibility of VR technologies in dementia therapy and care has not yet been sufficiently investigated [18]. Only a few studies with small sample sizes have examined the feasibility of VR in people with dementia [24]. In particular, direct changes in motor, cognitive, psychological, and physiological parameters, which are particularly important for the safety of people with dementia in everyday nursing home life, have scarcely been investigated following the use of VR technologies. In this context, it is important to take a closer look at cybersickness, which could increase the risk of falling after the use of VR technologies and is associated with injuries requiring hospitalization [25] and a decrease in activity, mobility, and quality of life [26]. Similarly, for an iVR intervention to be sustainable in nursing homes, there should be no deterioration in motor performance, confusion, and anxiety after iVR use. The feasibility of iVR in terms of safe use in people with dementia regarding influencing motor, cognitive, or emotional factors is currently inconclusive [27,28].

Therefore, the primary aim of this study is to investigate the feasibility of using iVR in people with dementia or MCI in nursing homes from a safety perspective. The focus of this study is to investigate any adverse effects of iVR on motor and cognitive function and general well-being. In particular, this study examines motor performance (including balance and mobility), cognitive performance (such as global cognition and executive function), emotional responses, and fear of falling before and after the single iVR use. This study can be seen as a preliminary step in assessing the suitability of iVR for physical training in people with dementia in nursing homes.

Methods

Ethical Considerations

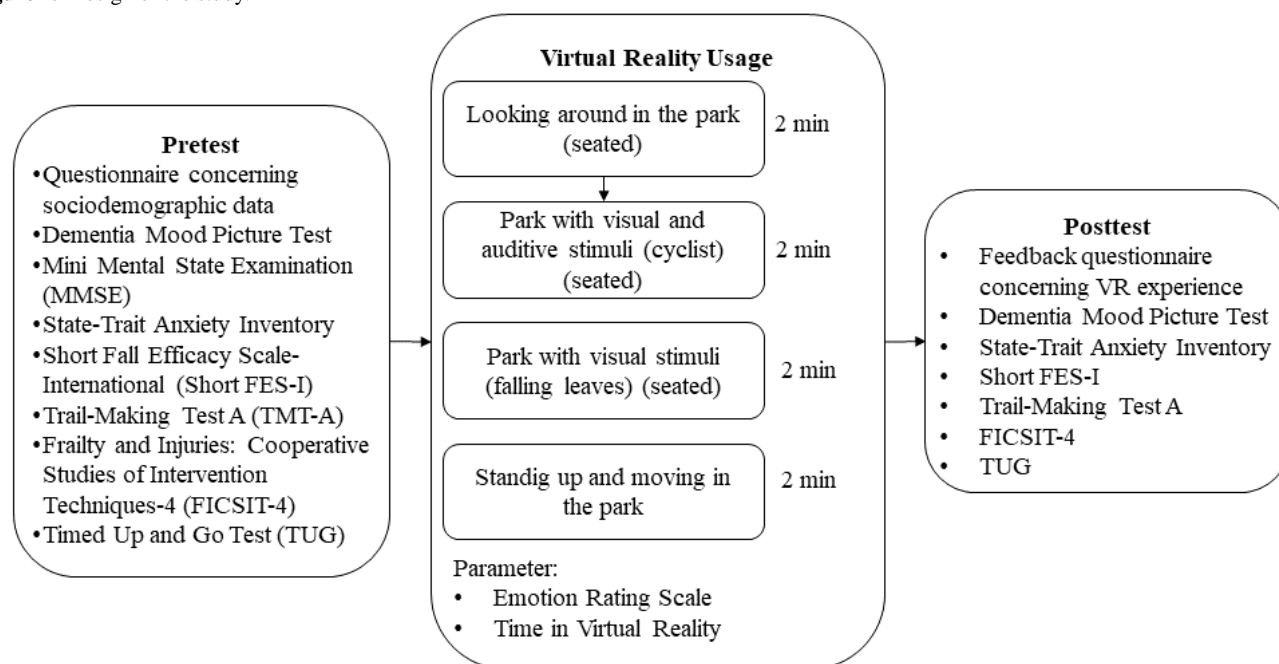
The research protocol followed the Declaration of Helsinki and ethical approval was granted by the Ethics Committee of the Otto-von-Guericke University Magdeburg (number 131/22) and the Karlsruhe Institute of Technology. The study was registered in the German Clinical Trials Register (DRKS00030616). The participants and their legal guardians provided written informed consent after being briefed on the study's details. Data were collected from December 2022 to July 2023. Participants were not offered any incentives/compensation for participation.

Study Design and Sample

The study was designed as a pre-post study to examine possible side effects of iVR by comparing motor and cognitive functions and emotional responses before and after iVR use (see Figure 1). All measurements were carried out in a single session lasting approximately 45 minutes. In each of the 2 cities, Magdeburg and Karlsruhe, 3 facilities were contacted to identify potential participants with the help of nursing home staff. The following inclusion criteria were applied: age over 70 years, MCI or mild to moderate dementia based on the Mini-Mental State Examination (MMSE [29]), no untreated hearing or visual

impairment, and self-sufficiency in standing and walking unaided or with a rollator. Exclusion criteria included hypertension, severe cardiovascular disease, and significant motor impairment. To check the inclusion criteria, a questionnaire on the sociodemographic data was completed together with the participants' legal guardians before the start of the study. Initially, 35 participants were included in the study, 23 (66%) in Magdeburg and 12 (34%) in Karlsruhe. Prior to the baseline assessments, the participants and their legal guardians were informed about the aims of the study, and written informed consent was obtained from the participants' legal guardians.

Figure 1. Design of the study.



Test Battery

To test the feasibility of iVR in people with dementia and its impact on motor performance, cognitive performance, and emotional response, the participants underwent several tests before and after the iVR application (Figure 1). The tests assessed the participants' mood using the Dementia Mood Picture Test [30], state and trait anxiety using the State-Trait Anxiety Inventory [31], fear of falling using the Short Falls Efficacy Scale-International (Short FES-I) [32], attention using the Trail-Making Test A (TMT-A) [33], balance performance using the FICSIT-4 (Frailty and Injuries: Cooperative Studies of Intervention Techniques-4) scale [34], and mobility using the Timed-Up-and-Go test (TUG) [35]. During the iVR use, the Emotion Rating Scale and another questionnaire adapted from Appel et al [27] (Multimedia Appendix 1) were applied. Additionally, after removing the HMD, participants completed a feedback questionnaire about their experience and general interest in VR.

In the Dementia Mood Picture Test, the participants are presented with 6 emoticons expressing different moods (negative mood, positive mood, cheerfulness, concern, sadness, and anger). Participants are asked to choose the emoticon that best describes their current mood. Cheerful is considered the best,

followed by a positive mood. In the State-Trait Anxiety Inventory, participants are asked to rate their general and current emotional state. A score is calculated based on the answers given, with higher scores being associated with higher levels of anxiety (state and trait max. 80 points [31]). The Short FES-I asks participants about their fear of falling in various situations. The score is also calculated based on the answers given, and again, with higher scores associated with a greater fear of falling (maximum 28 points [32]). To complete the TMT-A, the participants enter numbers 1 to 25 (jumbled together on a paper) in ascending order. The time taken and the number of errors made are recorded, with a shorter time and fewer errors associated with better attention. The FICSIT-4 tests 4 successive levels of static balance (bilateral stance, semitandem stance, tandem stance, and unilateral stance), each performed with eyes open and closed. Points are awarded according to the duration of each level (maximum 10 seconds). These points are summed up to give a total score (maximum 28 points), with higher scores associated with better static balance performance [34]. For the TUG test, participants are asked to stand up from a chair, walk 3 meters, turn 180°, walk back to the chair, and sit down again. The time taken to complete this task is measured, with a shorter time associated with a lower risk of falling [35].

The Emotion Rating Scale was scored by a test instructor during iVR use by observing participants' facial expressions. The emotional expressions (happiness, anger, fear, sadness, and general attention) and their duration (never, less than 16 seconds, 16 to 59 seconds, 1 to 5 minutes, and over 5 minutes) were documented.

The feedback questionnaire (Multimedia Appendix 1), which was administered after the iVR use, consisted of 17 questions (eg, "Did you like the VR?"), which were scored from one to five points, with more points indicating a higher level of agreement. The answers to negative questions (eg, "Did you feel nauseous while watching the VR?") were inverted. The questions were divided into 3 dimensions: "Response to VR" (questions 2, 6, 7, 10, 11, 15, 16), "Feedback to VR" (questions 1, 3, 4, 5, 8, 9), and "Comfort" (questions 12, 13, 14, and 17). The points were later summed up to dimension scores and a total score (maximum 85 points).

Virtual Reality Setup

During the iVR use, the participants sat on a chair between 2 SteamVR Base Stations (version 2.0; HTC Corp), which tracked the position of the HMD (Figure 2). The Pimax Vision 5k super (Pimax Inc) (170° horizontal FOV, 2560 x 1440 pixels per eye, 90 Hz refresh rate) was wired to a computer via cable and presented the virtual environments, which consisted of different scenes provided as 360° videos recorded in the Geschwister-Scholl-Park in Magdeburg, using the GoPro Hero 8 (GoPro Inc) (Figure 2). These videos were projected onto the inner surface of a virtual sphere (radius of 50 m) modeled with Blender (version 3.2; Blender Foundation). The virtual environments were then constructed using Unity (Unity Technologies). Self-written C# scripts were used to enable dynamic scene control within iVR, by allowing seamless scene transitions and pauses with simple button presses on a standard keyboard used by the test instructors. SteamVR (version 1.25.1; Valve Corp) was used to transfer the scenes from Unity to the HMD.

Figure 2. Virtual reality setup. Chair between 2 SteamVR Base Stations 2.0 with Pimax Vision 5k super (top). Participant with head-mounted display (HMD) and virtual park environment (bottom).



Procedure

After the pretest, the iVR use began, consisting of 4 scenes, each showing the same specific section of a park presented as a 360° video for 2 minutes. First, the HMD was demonstrated to the participants and placed on their heads. Once they were comfortable, the first scene began, showing the park without any additional elements (see Figure 3). During the first scene, the participants were asked to look around and describe the environment. The second scene showed a cyclist riding through the same section of the park, signaling their presence by ringing

a bell. In the third scene, the participants saw leaves falling to the ground, controlled by the instructor pressing the space bar on the computer keyboard. The final scene was identical to the first, but the participants were asked to stand up and walk a few steps if they wished and if the instructors and nursing staff felt it was feasible. While standing, the participants were always secured by at least 2 instructors. The scenes were presented directly, one after the other, without a break. After the last scene, the HMD was removed from the participants' heads, and the feedback questionnaire was administered. The posttest was then completed to detect deviations from the baseline measurement.

Figure 3. Immersive virtual reality (iVR) park environment (top, mid) with cyclist (bottom).



Statistical Analysis

Statistical data analysis was performed using SPSS (version 28.0; IBM Corp). The pre- and posttests (State-Trait Anxiety Inventory, Short FES-I, TMT-A, FICSIT-4, and TUG) were compared using paired t tests. If the prerequisites for a t test were unmet, the Wilcoxon test was used instead. The significance level was set at $\alpha=.05$. To avoid the cumulation of alpha errors, the significance level was adjusted using the Bonferroni-Holm correction. Cohen classification was used to interpret the effect sizes ($d=0.2/r=0.1$, small; $d=0.5/r=0.3$, moderate; $d=0.8/r=0.5$, large). The Dementia Mood Picture Test, MMSE, Emotion Rating Scale, and feedback questionnaire were analyzed descriptively.

Results

Sample characteristics

Two participants dropped out during the study, corresponding to a dropout rate of 6%. The first participant signaled disinterest at the beginning of the measurement day and dropped out immediately, while the other participant was bothered by the HMD and wanted to take it off. Thus, 33 (94%) of the 35 people with dementia (mean age 83.71, SD 5.01 years) were analyzed in the study. Table 1 shows the sample characteristics.

Care was taken to ensure that participants with dementia had no untreated visual or hearing impairments. The HMD could also be used with visual and/or hearing aids.

Table 1. Sample characteristics.

Characteristics	Sample (N=33)
Age (years), mean (SD)	83.71 (5.01)
MMSE ^a score, mean (SD)	21.2 (4.2)
Sex, n (%)	
Male	7 (21.2)
Female	26 (78.8)
Experience with VR ^b ; n (%)	6 (18.2)
Degree of dementia n (%)	
No dementia	1 (3)
Mild dementia	21 (63.6)
Moderate dementia	11 (33.3)

^aMMSE: Mini-Mental State Examination.

^bVR: virtual reality.

Outcome Parameters

Feasibility

Observations of the participants during the iVR use revealed that 72% (n=24) felt pleasure and fun, as measured by the Emotion Rating Scale. Additionally, all 33 (100%) participants showed no fear, sadness, or anger during the iVR use, and 31 (93%) out of 33 patients were attentive and able to respond to everything in the environment and thus interact with the iVR (Figure 4).

The feedback form according to Appel et al [27] showed that the participants rated the iVR as positive on average. The total score was 73.21 (SD 7.1) out of a possible 85 points. This is

also reflected in the individual dimension of the questionnaire, as outlined in the Methods section. The participants responded very positively to the iVR use. On average, the participants rated this dimension 31.2 out of 35 points. The participants also gave positive feedback on the iVR, by rating this dimension with 24.9 out of 30 points. The final dimension, comfort, was rated positively with 17 out of 20 points (see Figure 5). The questions of the dimensions can be found in Multimedia Appendix 1. Additionally, the actual time spent in iVR was recorded showing an average of 389 seconds (6.5 seconds minimum; the maximum was 480 seconds or 8 minutes). The first 3 scenes (Figure 1) were completed without issue; some participants did not want to try scene 4 (standing up).

Figure 4. Results of the Emotion Rating Scale.

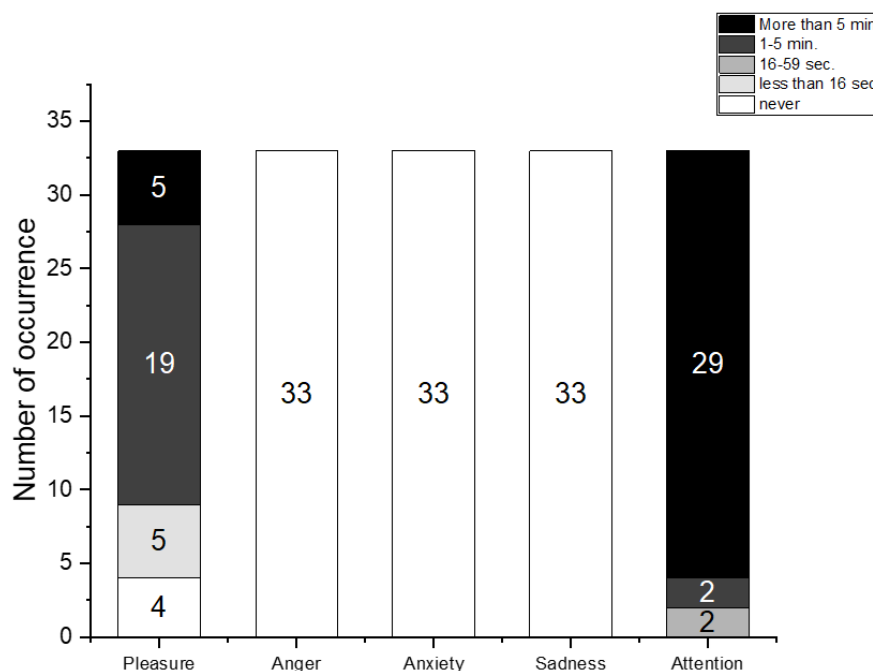
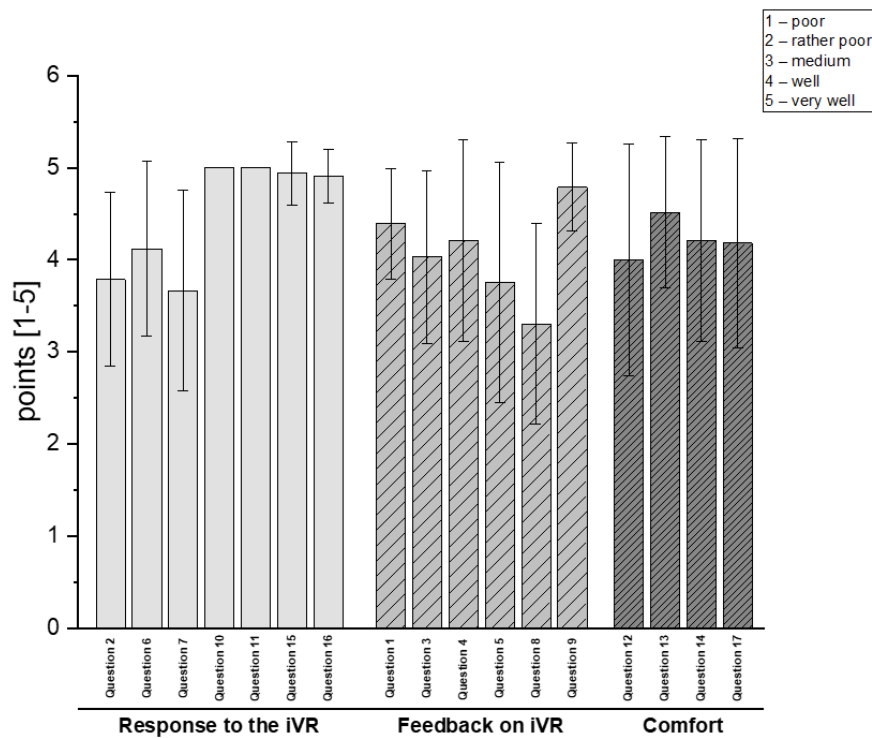


Figure 5. Results of the protocol response after immersive virtual reality (iVR) use.

Motor and Cognitive Performance and Mental State

The results show no significant changes in cognitive and motor performance and mental state after iVR (Table 2) (TMT-A: $t_{26}=1.244$, correct $P>.99$; state anxiety: $t_{32}=1.653$, correct $P=.65$; trait anxiety: $t_{32}=1.754$, correct $P=.53$; FICSIT-4: $t_{29}=-2.531$, correct $P=.16$; TUG: $t_{28}=-0.036$, correct $P>.99$; short FES-I: $z=-1.461$, correct $P=.68$). However, almost all parameters showed slight but not statistically significant improvement after iVR use. On the TMT-A, people with dementia improved by a

mean of 9.5 seconds. State anxiety and trait anxiety improved by 2.65 and 3.39 points, respectively. The FICSIT-4 showed an increase of 1.44 points from pre- to posttest. The results of the TUG and the short FES-I did not change.

The Dementia Mood Picture Test also reflects a slight improvement: 27 (82%) out of 33 participants were in a good mood before iVR, and 6 (18%) were cheerful. After iVR, the distribution of the 2 moods was balanced so that 16 (49%) out of 33 participants were in a good mood and 17 (51%) were in a cheerful mood.

Table 2. Results of the pre- and posttest.

Outcomes	Pretest, mean (SD) (95% CI)	posttest, mean (SD) (95% CI)	<i>P</i> value (Bonferroni-Holm)	Effect size (<i>d</i>)
Parametric tests (<i>t</i> test)				
TMT-A ^a (n=27)	118.43 (70.10) (90.67-146.20)	108.91 (80.60) (77.01-140.8)	.225 (>.999)	0.24
State anxiety (points) (n=33)	33.94 (8.36) (29.42-36.46)	31.29 (10.25) (26.31-34.28)	.108 (.648)	0.28
Trait anxiety (points) (n=33)	33.45 (8.69) (28.87-36.07)	30.06 (10.51) (25.14-33.21)	.089 (.534)	0.30
FICSIT-4 ^b (points); n=30	15.63 (5) (13.76-17.51)	17.07 (5.10) (15.16-18.98)	.026 (.156)	0.43
TUG ^c (n=29)	15.53 (5.60) (13.41-17.65)	15.56 (5.50) (13.47-17.65)	.976 (>.999)	0.007
Nonparametric tests (Wilcoxon test)				
Short FES-I ^d (points) (n=33)	7.50 ^a (7.00-11.25)	7.00 ^a (7.00-10.00)	.114 (.684)	0.25 ^e

^aTMT-A: Trail-Making Test A.

^bFICSIT-4: Frailty and Injuries: Cooperative Studies of Intervention Techniques-4.

^cTUG: Timed-Up-and-Go.

^dFES-I: Falls Efficacy Scale-International.

^e Median and 25th/75th percentile, Correlation coefficient *r*.

Discussion

Principal Findings and Comparison to Prior Work

This study demonstrates the feasibility of using iVR in people with dementia without significant changes or effects on emotional, cognitive, or physical outcomes. Thus, no negative side effects were observed following iVR use. Out of 35 participants, only 2 dropped out during the study, and only 1 of these was due to the participant feeling disturbed by the HMD. Thus, the dropout rate for iVR use was low, which is comparable to Appel et al [27], who observed iVR use in people with cognitive and/or physical impairments and Thapa et al [22] who analyzed iVR use in people with MCI. Liao et al [23] reported a higher dropout rate (8 out of 42) in people with MCI due to low motivation during the iVR use, but this was a 12-week intervention. Other studies using VR in people with dementia did not report dropout rates, so no further comparisons are available [36,37].

In general, it might have been expected that people with dementia would have challenges participating in the iVR [38]. On the one hand, there is a lack of haptic feedback, and on the other, there is acoustic information from the real world (eg, instructors speaking and birds singing in the iVR at the same time). The feasibility of using iVR can be positively rated by the average time participants used the iVR, which was 6.5 minutes (out of a maximum of 8 minutes). Additionally, the reasons for discontinuing iVR use, which were more due to the low-stimulus environment rather than excessive demands or overstimulation, also indicate good feasibility. The first 3 scenes of iVR use could be followed by all participants without any issues.

Most of the participants (n=31, 93%) were attentive during the iVR experience, which has not been reported previously. As far as we know, Mendez et al [36] only found that the participants' talkativeness increased while wearing an outdated HMD that did not allow full immersion. Pleasant feelings such as joy or fun were observed in the majority of participants, particularly in 5 (15%) participants over a longer period (>5 min). This is a positive observation, and it echoes the study by Appel et al [27], where VR exposure was generally considered to be enjoyable. In addition to the positive emotional reactions, the question arises as to whether confusion, which occurs disproportionately often in people with dementia [39], is related to the use of VR. Confusion or challenging behavior may be associated with extreme or extremely negative emotions [40], which we sought to observe during the iVR use. In our study, no participant showed anxiety, sadness, or anger during iVR use. Thus, our findings agree with those of Appel et al [27] and Mendez et al [36] regarding negative emotions.

The emotional observations are particularly important for future long-term use in an iVR intervention, as a sustainable intervention in nursing homes should only be implemented if additional benefits in the real world are observed. The joy and attention experienced, combined with the absence of fear, anger, and sadness, suggest a positive impact on the quality of life. Regarding challenging behavior among people with dementia in nursing homes and home care [41], future studies could also investigate whether positive outcomes can be achieved through iVR use.

Since people with dementia are known to face challenges in correctly identifying and associating negative emotions [42], the questions about the iVR use were particularly relevant and

helpful in correctly classifying the observations. Our results show that participants generally rated the iVR use as positive, as assessed by the feedback questionnaire based on Appel et al [27]. The responses to the questions are summarized under the 3 dimensions of response, feedback, and comfort.

The general response to the iVR use was assessed by questionnaire items such as, “This helped you to relax and free yourself from unwanted feelings or thoughts,” “You felt like you were panicking when you saw this,” or “Did you get dizzy while watching VR?” All questions about dizziness or nausea, as well as confusion or disorientation, were answered in the negative, so no negative effects are to be expected. Similar results were also reported by Appel et al [27], who found that 92% of respondents did not experience nausea while using VR and that other side effects such as dizziness, disorientation, or confusion were not detected. The general response to the use of iVR can therefore be considered positive, which was also shown in the feedback subdimension. Questionnaire items were asked regarding this realm, such as, “The virtual world appeared to be very real to you,” “This was fascinating to observe,” or “You want to spend more time viewing this environment.”

Questions about the comfort of the HMD included whether participants were able to get used to the HMD, whether they found the HMD heavy, and whether they were able to move their heads well. High scores were found for these items, so the comfort of the HMD can be rated as very good. This was also reported by Appel et al [27], where 88% of the participants negated the question, “Did the VR HMD feel too heavy?” In general, however, this assessment must be qualified in the sense that the participants in our study only used the HMD for a relatively short period of time and did not perform any guided movements with it.

There were no statistically significant changes in motor and cognitive performance or mental state after the single use of iVR. Side effects from iVR use can therefore be ruled out. This is a particularly positive finding for people with dementia, as it could be expected that negative effects such as dizziness or nausea may occur after just a few minutes of using iVR [38]. The nonsignificant improvements in almost all tests and questionnaires after iVR use suggest a learning effect due to the short time interval between measurements. Assumptions that the improvements are also due to an improvement in mood, as has been found in people with depression [43], are speculative and need to be investigated in further studies. To assess the changes, it is important that physical and cognitive performance does not decline significantly after the use of iVR, as this would lead to an increased risk of falls and thus more intensive care.

State anxiety and trait anxiety also improved and may also be related to positive emotions. The more positive emotions were reflected in a change in the Dementia Mood Picture Test, which showed better mood scores after iVR use, along with cheerful feelings, which may be related to a more positive mood. While the results for mobility and fear of falling remained the same, there were changes in balance after iVR use. This has not been previously reported and cannot be explained presently. The mean differences in the FICSIT-4 test meet the threshold of the minimal clinically important difference [44], but the results are

not statistically significant and can therefore only be interpreted as trends. This may indicate a possible effect of longer-term interventions, which needs to be verified in future studies. In addition to the findings on balance, mobility, and fear of falling, we observed that some participants did not want to try to stand up with the HMD iVR system. This suggests that some participants may have felt unsafe while using iVR, which needs to be considered for future iVR interventions, especially those involving increased physical activation.

Strengths and Limitations

The strength of this study is the use of iVR for people with dementia under real conditions in nursing homes. To date, there have been few studies of this nature, and we were able to show that the use of iVR in nursing homes is feasible and is not expected to have a negative impact on people with dementia.

As with any study, there are several limitations. The first is the rather low-stimulation VR environment, where there was no direct activation in the form of physical activity. The rationale was to investigate the general feasibility and gain experiences with iVR for people with dementia to assess and possibly minimize the risks of such VR uses. This was particularly necessary for this target group to gain a first impression and can therefore be seen as a preliminary step in assessing the suitability of iVR for physical activity in people with dementia in nursing homes. We aimed to avoid situations that could lead to cognitive disorientation, emotional reactions, or physical responses such as dizziness. The second limitation is the relatively small sample size, which, although considered appropriate for the study design and objectives, does not allow for generalization. Additionally, the sample had a rather mild degree of dementia, which limits the generalizability to the whole population of people with dementia. The third limitation is the single use of iVR in a predominantly seated position. The single use of iVR and the predominantly seated position influenced the interaction and incentive to be physically active, at the same time legitimizing and strengthening the use of iVR to promote physical activity. Therefore, the duration of the intervention, the sample included, and a critical review of the cost-benefit ratio need to be included in future studies.

Future Directions

Future studies should build on these findings by including more stimulating environments that encourage more physical activity. Such environments could potentially increase engagement and movement to exercise, overcoming the limitations of this study's low-stimulation VR environment. To this end, the feasibility of computer-generated virtual environments for people with dementia should be examined, as they provide a higher degree of individualization and interaction compared to 360° videos. Additionally, longer-term iVR interventions with multiple sessions should be investigated to assess lasting effects on motor and cognitive performance. Future research should also investigate the potential of iVR to positively impact the quality of life of people with dementia by examining its effects on mood, emotional well-being, and general engagement. Finally, the economic feasibility of implementing iVR interventions needs to be considered. Future studies should include cost-benefit analyses to determine the overall value and

feasibility of iVR as a regular intervention in care settings. By addressing these areas, future research can further elucidate the potential of iVR to improve the well-being of people with dementia and contribute to the development of effective and scalable interventions.

Conclusion

The changes observed in our study due to the use of iVR do not indicate that the use of iVR increases the risk of falling or causes adverse effects such as dizziness or nausea. Therefore, we can

conclude that iVR use can be applied in nursing homes for people with dementia or MCI and that no debilitating emotional, cognitive, or physical changes are to be expected afterward. However, care must be taken during iVR use to ensure that there are no events that increase the risk of falling. In this study, which involved a single use of iVR in a predominantly seated position and a relatively low stimulus iVR environment, there were no complications. Further studies are needed to investigate prolonged use with a more stimulating environment and possible physical and cognitive tasks in people with dementia.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Assessment battery.

[DOCX File, 24 KB - [xr_v1i1e54724_app1.docx](#)]

References

1. GBD 2019 Dementia Forecasting Collaborators. Estimation of the global prevalence of dementia in 2019 and forecasted prevalence in 2050: an analysis for the Global Burden of Disease Study 2019. *Lancet Public Health* 2022 Feb;7(2):e105-e125 [FREE Full text] [doi: [10.1016/S2468-2667\(21\)00249-8](#)] [Medline: [34998485](#)]
2. Global status report on the public health response to dementia. World Health Organization. URL: <https://www.who.int/publications-detail-redirect/9789240033245> [accessed 2023-11-18]
3. Jönsson L, Tate A, Frisell O, Wimo A. The costs of dementia in Europe: an updated review and meta-analysis. *Pharmacoeconomics* 2023 Jan 15;41(1):59-75 [FREE Full text] [doi: [10.1007/s40273-022-01212-z](#)] [Medline: [36376775](#)]
4. Bessey LJ, Walaszek A. Management of behavioral and psychological symptoms of dementia. *Curr Psychiatry Rep* 2019 Jul 01;21(8):66. [doi: [10.1007/s11920-019-1049-5](#)] [Medline: [31264056](#)]
5. Farina N, Rusted J, Tabet N. The effect of exercise interventions on cognitive outcome in Alzheimer's disease: a systematic review. *Int Psychogeriatr* 2013 Aug 20;26(1):9-18. [doi: [10.1017/s1041610213001385](#)]
6. Sofi F, Valecchi D, Bacci D, Abbate R, Gensini GF, Casini A, et al. Physical activity and risk of cognitive decline: a meta-analysis of prospective studies. *J Intern Med* 2011 Jan;269(1):107-117 [FREE Full text] [doi: [10.1111/j.1365-2796.2010.02281.x](#)] [Medline: [20831630](#)]
7. Zhou S, Chen S, Liu X, Zhang Y, Zhao M, Li W. Physical activity improves cognition and activities of daily living in adults with Alzheimer's disease: a systematic review and meta-analysis of randomized controlled trials. *Int J Environ Res Public Health* 2022 Jan 22;19(3):1216 [FREE Full text] [doi: [10.3390/ijerph19031216](#)] [Medline: [35162238](#)]
8. Deslandes A, Moraes H, Ferreira C, Veiga H, Silveira H, Mouta R, et al. Exercise and mental health: many reasons to move. *Neuropsychobiology* 2009;59(4):191-198 [FREE Full text] [doi: [10.1159/000223730](#)] [Medline: [19521110](#)]
9. Begde A, Jain M, Hogervorst E, Wilcockson T. Does physical exercise improve the capacity for independent living in people with dementia or mild cognitive impairment: an overview of systematic reviews and meta-analyses. *Aging Ment Health* 2022 Dec;26(12):2317-2327 [FREE Full text] [doi: [10.1080/13607863.2021.2019192](#)] [Medline: [34951548](#)]
10. Logsdon R, McCurry SM, Teri L. Evidence-based interventions to improve quality of life for individuals with dementia. *Alzheimer's Care Today* 2007;8(4):309-318 [FREE Full text] [Medline: [19030120](#)]
11. Liang Y, Su Q, Sheng Z, Weng Q, Niu Y, Zhou H, et al. Effectiveness of physical activity interventions on cognition, neuropsychiatric symptoms, and quality of life of Alzheimer's disease: an update of a systematic review and meta-analysis. *Front Aging Neurosci* 2022;14:830824 [FREE Full text] [doi: [10.3389/fnagi.2022.830824](#)] [Medline: [35309887](#)]
12. Neves A, Lygidakis C, Hoedebecke K, De PL, Pilotto A. *Digital Health in an Ageing World*. Cham, Switzerland: Springer International Publishing; 2022.
13. Dörner R, Broll W, Grimm P, Jung B. *Virtual und Augmented Reality (VR/AR): Grundlagen und Methoden der Virtuellen und Augmentierten Realität*. Berlin, Germany: Springer; 2019.
14. Dargar S, Kennedy R, Lai W, Arikatla V, De S. Towards immersive virtual reality (iVR): a route to surgical expertise. *J Comput Surg* 2015 May;2 [FREE Full text] [doi: [10.1186/s40244-015-0015-8](#)] [Medline: [26478852](#)]

15. Clay F, Howett D, FitzGerald J, Fletcher P, Chan D, Price A. Use of Immersive Virtual Reality in the Assessment and Treatment of Alzheimer's Disease: A Systematic Review. *J Alzheimers Dis* 2020;75(1):23-43 [FREE Full text] [doi: [10.3233/JAD-191218](https://doi.org/10.3233/JAD-191218)] [Medline: [32280091](https://pubmed.ncbi.nlm.nih.gov/32280091/)]
16. Slater M, Sanchez-Vives MV. Enhancing our lives with immersive virtual reality. *Front Robot AI* 2016 Dec 19;3:1449682 [FREE Full text] [doi: [10.3389/frobt.2016.00074](https://doi.org/10.3389/frobt.2016.00074)]
17. Skurla MD, Rahman AT, Salcone S, Mathias L, Shah B, Forester BP, et al. Virtual reality and mental health in older adults: a systematic review. *Int Psychogeriatr* 2021 Mar 24;1-13. [doi: [10.1017/S104161022100017X](https://doi.org/10.1017/S104161022100017X)] [Medline: [33757619](https://pubmed.ncbi.nlm.nih.gov/33757619/)]
18. Kim O, Pang Y, Kim J. The effectiveness of virtual reality for people with mild cognitive impairment or dementia: a meta-analysis. *BMC Psychiatry* 2019 Jul 12;19(1):219 [FREE Full text] [doi: [10.1186/s12888-019-2180-x](https://doi.org/10.1186/s12888-019-2180-x)] [Medline: [31299921](https://pubmed.ncbi.nlm.nih.gov/31299921/)]
19. Appel L, Ali S, Narag T, Mozeson K, Pasat Z, Orchanian-Cheff A, et al. Virtual reality to promote wellbeing in persons with dementia: A scoping review. *J Rehabil Assist Technol Eng* 2021;8:20556683211053952 [FREE Full text] [doi: [10.1177/20556683211053952](https://doi.org/10.1177/20556683211053952)] [Medline: [35024166](https://pubmed.ncbi.nlm.nih.gov/35024166/)]
20. Zhu S, Sui Y, Shen Y, Zhu Y, Ali N, Guo C, et al. Effects of virtual reality intervention on cognition and motor function in older adults with mild cognitive impairment or dementia: a systematic review and meta-analysis. *Front Aging Neurosci* 2021;13:586999 [FREE Full text] [doi: [10.3389/fnagi.2021.586999](https://doi.org/10.3389/fnagi.2021.586999)] [Medline: [34025384](https://pubmed.ncbi.nlm.nih.gov/34025384/)]
21. Wiebe A, Kannen K, Selaskowski B, Mehren A, Thöne AK, Pramme L, et al. Virtual reality in the diagnostic and therapy for mental disorders: A systematic review. *Clin Psychol Rev* 2022 Dec;98:102213 [FREE Full text] [doi: [10.1016/j.cpr.2022.102213](https://doi.org/10.1016/j.cpr.2022.102213)] [Medline: [36356351](https://pubmed.ncbi.nlm.nih.gov/36356351/)]
22. Thapa N, Park HJ, Yang J, Son H, Jang M, Lee J, et al. The effect of a virtual reality-based intervention program on cognition in older adults with mild cognitive impairment: a randomized control trial. *J Clin Med* 2020 Apr 29;9(5) [FREE Full text] [doi: [10.3390/jcm9051283](https://doi.org/10.3390/jcm9051283)] [Medline: [32365533](https://pubmed.ncbi.nlm.nih.gov/32365533/)]
23. Liao Y, Chen I, Lin Y, Chen Y, Hsu W. Effects of virtual reality-based physical and cognitive training on executive function and dual-task gait performance in older adults with mild cognitive impairment: a randomized control trial. *Front Aging Neurosci* 2019 Jul 16;11:162 [FREE Full text] [doi: [10.3389/fnagi.2019.00162](https://doi.org/10.3389/fnagi.2019.00162)] [Medline: [31379553](https://pubmed.ncbi.nlm.nih.gov/31379553/)]
24. Strong J. Immersive virtual reality and persons with dementia: a literature review. *J Gerontol Soc Work* 2020 Apr;63(3):209-226. [doi: [10.1080/01634372.2020.1733726](https://doi.org/10.1080/01634372.2020.1733726)] [Medline: [32091323](https://pubmed.ncbi.nlm.nih.gov/32091323/)]
25. Na'emani F, Esmail Zali M, Sohrabi Z, Fayaz-Bakhsh A. Prevalence of risk factors for falls among the elderly receiving care at home. *Salmand* 2019 Mar 30:638-651. [doi: [10.32598/sija.13.special-issue.638](https://doi.org/10.32598/sija.13.special-issue.638)]
26. Manckoundia P, Mourey F, Pérennou D, Pfitzenmeyer P. Backward disequilibrium in elderly subjects. *Clin Interv Aging* 2008;3(4):667-672 [FREE Full text] [doi: [10.2147/cia.s3811](https://doi.org/10.2147/cia.s3811)] [Medline: [19281059](https://pubmed.ncbi.nlm.nih.gov/19281059/)]
27. Appel L, Appel E, Bogler O, Wiseman M, Cohen L, Ein N, et al. Older adults with cognitive and/or physical impairments can benefit from immersive virtual reality experiences: a feasibility study. *Front Med (Lausanne)* 2019 Jan 15;6:329 [FREE Full text] [doi: [10.3389/fmed.2019.00329](https://doi.org/10.3389/fmed.2019.00329)] [Medline: [32010701](https://pubmed.ncbi.nlm.nih.gov/32010701/)]
28. Canning CG, Allen NE, Nackaerts E, Paul SS, Nieuwboer A, Gilat M. Virtual reality in research and rehabilitation of gait and balance in Parkinson disease. *Nat Rev Neurol* 2020 Aug;16(8):409-425. [doi: [10.1038/s41582-020-0370-2](https://doi.org/10.1038/s41582-020-0370-2)] [Medline: [32591756](https://pubmed.ncbi.nlm.nih.gov/32591756/)]
29. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res* 1975 Nov;12(3):189-198. [doi: [10.1016/0022-3956\(75\)90026-6](https://doi.org/10.1016/0022-3956(75)90026-6)] [Medline: [1202204](https://pubmed.ncbi.nlm.nih.gov/1202204/)]
30. Tappen RM, Barry C. Assessment of affect in advanced Alzheimer's disease: the Dementia Mood Picture Test. *J Gerontol Nurs* 1995 Mar 01;21(3):44-46. [doi: [10.3928/0098-9134-19950301-09](https://doi.org/10.3928/0098-9134-19950301-09)] [Medline: [7706649](https://pubmed.ncbi.nlm.nih.gov/7706649/)]
31. Spielberg C, Gorsuch R, Lushene R. Manual for the State-Trait Anxiety Inventory. Google Scholar. URL: https://scholar.google.com/scholar_lookup?&title=Manual%20for%20the%20State-Trait%20Anxiety%20Inventory&publication_year=1970&author=Spielberger%20CCD&author=Gorsuch%20CRL&author=Lushene%20CRE [accessed 2023-11-20]
32. Kempen GIJM, Yardley L, van Haastregt JCM, Zijlstra GAR, Beyer N, Hauer K, et al. The Short FES-I: a shortened version of the falls efficacy scale-international to assess fear of falling. *Age Ageing* 2008 Jan 11;37(1):45-50. [doi: [10.1093/ageing/afm157](https://doi.org/10.1093/ageing/afm157)] [Medline: [18032400](https://pubmed.ncbi.nlm.nih.gov/18032400/)]
33. Reitan R. The relation of the trail making test to organic brain damage. *J Consult Psychol* 1955 Oct;19(5):393-394. [doi: [10.1037/h0044509](https://doi.org/10.1037/h0044509)] [Medline: [13263471](https://pubmed.ncbi.nlm.nih.gov/13263471/)]
34. Rossiter-Fornoff JE, Wolf SL, Wolfson LI, Buchner DM. A cross-sectional validation study of the FICSIT common data base static balance measures. *Frailty and Injuries: Cooperative Studies of Intervention Techniques. J Gerontol A Biol Sci Med Sci* 1995 Nov 01;50(6):M291-M297. [doi: [10.1093/gerona/50a.6.m291](https://doi.org/10.1093/gerona/50a.6.m291)] [Medline: [7583799](https://pubmed.ncbi.nlm.nih.gov/7583799/)]
35. Podsiadlo D, Richardson S. *J Am Geriatr Soc* 1991 Mar 27;39(2):142-148. [doi: [10.1111/j.1532-5415.1991.tb01616.x](https://doi.org/10.1111/j.1532-5415.1991.tb01616.x)] [Medline: [1991946](https://pubmed.ncbi.nlm.nih.gov/1991946/)]
36. Mendez MF, Joshi A, Jimenez E. Virtual reality for the assessment of frontotemporal dementia, a feasibility study. *Disabil Rehabil Assist Technol* 2015 Mar;10(2):160-164. [doi: [10.3109/17483107.2014.889230](https://doi.org/10.3109/17483107.2014.889230)] [Medline: [24524440](https://pubmed.ncbi.nlm.nih.gov/24524440/)]
37. Fernandez Montenegro JM, Argyriou V. Cognitive evaluation for the diagnosis of Alzheimer's disease based on Turing test and virtual environments. *Physiol Behav* 2017 May 01;173:42-51 [FREE Full text] [doi: [10.1016/j.physbeh.2017.01.034](https://doi.org/10.1016/j.physbeh.2017.01.034)] [Medline: [28137425](https://pubmed.ncbi.nlm.nih.gov/28137425/)]

38. Huygelier H, Schraepen B, van Ee R, Vanden Abeele V, Gillebert CR. Acceptance of immersive head-mounted virtual reality in older adults. *Sci Rep* 2019 Mar 14;9(1):4519 [FREE Full text] [doi: [10.1038/s41598-019-41200-6](https://doi.org/10.1038/s41598-019-41200-6)] [Medline: [30872760](https://pubmed.ncbi.nlm.nih.gov/30872760/)]
39. Abraha I, Rimland JM, Trotta FM, Dell'Aquila G, Cruz-Jentoft A, Petrovic M, et al. Systematic review of systematic reviews of non-pharmacological interventions to treat behavioural disturbances in older patients with dementia. The SENATOR-OnTop series. *BMJ Open* 2017 Mar 16;7(3):e012759 [FREE Full text] [doi: [10.1136/bmjopen-2016-012759](https://doi.org/10.1136/bmjopen-2016-012759)] [Medline: [28302633](https://pubmed.ncbi.nlm.nih.gov/28302633/)]
40. Ooi CH, Yoon PS, How CH, Poon NY. Managing challenging behaviours in dementia. *Singapore Med J* 2018 Oct;59(10):514-518 [FREE Full text] [doi: [10.11622/smedj.2018125](https://doi.org/10.11622/smedj.2018125)] [Medline: [30386856](https://pubmed.ncbi.nlm.nih.gov/30386856/)]
41. Feast A, Orrell M, Charlesworth G, Melunsky N, Poland F, Moniz-Cook E. Behavioural and psychological symptoms in dementia and the challenges for family carers: systematic review. *Br J Psychiatry* 2016 May;208(5):429-434 [FREE Full text] [doi: [10.1192/bjp.bp.114.153684](https://doi.org/10.1192/bjp.bp.114.153684)] [Medline: [26989095](https://pubmed.ncbi.nlm.nih.gov/26989095/)]
42. Hwang S, Hwang J, Jeong H. Study on associating emotions in verbal reactions to facial expressions in dementia. *Healthcare (Basel)* 2022 Jun 01;10(6):1022 [FREE Full text] [doi: [10.3390/healthcare10061022](https://doi.org/10.3390/healthcare10061022)] [Medline: [35742073](https://pubmed.ncbi.nlm.nih.gov/35742073/)]
43. Kraft B, Bø R, Jonassen R, Heeren A, Ulset VS, Stiles TC, et al. The association between depression symptoms and reduced executive functioning is primarily linked by fatigue. *Psychiatry Research Communications* 2023 Jun;3(2):100120. [doi: [10.1016/j.psycom.2023.100120](https://doi.org/10.1016/j.psycom.2023.100120)]
44. Blankevoort CG, van Heuvelen MJG, Scherder EJA. Reliability of six physical performance tests in older people with dementia. *Phys Ther* 2013 Jan;93(1):69-78 [FREE Full text] [doi: [10.2522/ptj.20110164](https://doi.org/10.2522/ptj.20110164)] [Medline: [22976448](https://pubmed.ncbi.nlm.nih.gov/22976448/)]

Abbreviations

FICSIT-4: Frailty and Injuries: Cooperative Studies of Intervention Techniques-4

HMD: head-mounted display

iVR: immersive virtual reality

MCI: mild cognitive impairment

MMSE: Mini-Mental State Examination

Short FES-I: Short Falls Efficacy Scale-International

TMT-A: Trail-Making Test A

TUG: Timed-Up-and-Go Test

VR: virtual reality

Edited by T Leung; submitted 20.11.23; peer-reviewed by DD Larson MD, L Sheehy; comments to author 28.03.24; revised version received 23.04.24; accepted 18.07.24; published 21.08.24.

Please cite as:

Prinz A, Buerger D, Krafft J, Bergmann M, Woll A, Barisch-Fritz B, Witte K

Use of Immersive Virtual Reality in Nursing Homes for People With Dementia: Feasibility Study to Assess Cognitive, Motor, and Emotional Responses

JMIR XR Spatial Comput 2024;1:e54724

URL: <https://xr.jmir.org/2024/1/e54724>

doi: [10.2196/54724](https://doi.org/10.2196/54724)

PMID:

©Alexander Prinz, Dan Buerger, Jelena Krafft, Matteo Bergmann, Alexander Woll, Bettina Barisch-Fritz, Kerstin Witte. Originally published in *JMIR XR and Spatial Computing* (<https://xr.jmir.org>), 21.08.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in *JMIR XR and Spatial Computing*, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Original Paper

Immediate Impact of an 8-Week Virtual Reality Educational Program on Burnout and Work Engagement Among Health Care Professionals: Pre-Post Pilot Study

Jose Ferrer Costa¹, MD; Nuria Moran², MD; Carlos Garcia Marti², MD; Leomar Javier Colmenares Hernandez², MD; Florin Radu Ciorba Ciorba², MD; Maria Jose Ciudad^{3,4}, MSc

¹Innovation and Projects Department, Badalona Serveis Assistencials, Badalona, Spain

²Primary Care Service, Badalona Serveis Assistencials, Badalona, Spain

³Centre Sociosanitari El Carme, Badalona Serveis Assistencials, Badalona, Spain

⁴Department of Clinical Psychology and Psychobiology, Faculty of Psychology, Universitat de Barcelona, Barcelona, Spain

Corresponding Author:

Jose Ferrer Costa, MD

Innovation and Projects Department

Badalona Serveis Assistencials

Pl Pau Casals 1

Badalona, 08911

Spain

Phone: 34 937407482

Email: jferrer10@gmail.com

Abstract

Background: Health care professionals globally face increasing levels of burnout characterized by emotional exhaustion, depersonalization, and a reduced sense of accomplishment, and it has been notably exacerbated during the COVID-19 pandemic. This condition not only impacts the well-being of health care workers but also affects patient care and contributes to significant economic burden. Traditional approaches to mitigating burnout have included various psychosocial interventions, with mindfulness being recognized for its effectiveness in enhancing mental health and stress management. The emergence of virtual reality (VR) technology offers a novel immersive platform for delivering mindfulness and emotional management training.

Objective: This study aimed to evaluate the immediate impact of an 8-week VR educational program on burnout and work engagement among health care professionals.

Methods: This nonrandomized pre-post intervention study enrolled 90 health care professionals, including nurses, physicians, and allied health staff, from 3 different centers. Of these 90 professionals, 83 (92%) completed the program. The intervention consisted of 8 weekly VR sessions of 10-13 minutes each, using Meta Quest 2 headsets. The sessions focused on mindfulness and emotional management. The Maslach Burnout Inventory (MBI) and Utrecht Work Engagement Scale (UWES) were used for assessments. Data analysis involved inferential statistical techniques for evaluating the impact on the scales, including paired *t* tests for normally distributed variables and Wilcoxon signed rank tests for nonnormally distributed variables. The significance of changes was indicated by *P* values <.05, with effect sizes measured using Cohen *d* for *t* tests and Cohen *r* for Wilcoxon tests for quantifying the magnitude of the intervention's effect.

Results: The statistical analysis revealed significant improvements in the MBI and UWES indices after the intervention (*P*<.05). Specifically, the MBI showed reductions in emotional exhaustion ($t_{82}=5.58$; *P*<.001; Cohen *d*=0.61) and depersonalization ($t_{82}=4.67$; *P*<.001; Cohen *d*=0.51), and an increase in personal accomplishment ($t_{82}=-3.62$; *P*<.001; Cohen *d*=0.4). The UWES revealed enhancements in vigor ($t_{82}=-3.77$; *P*<.001; Cohen *d*=0.41), dedication ($Z=-3.63$; *P*<.001; Cohen *r*=0.41), and absorption ($Z=-3.52$; *P*<.001; Cohen *r*=0.4).

Conclusions: The study provides initial data supporting the effectiveness of VR-based educational programs for reducing burnout and enhancing work engagement among health care professionals. While limitations, such as the absence of a control group, are acknowledged, the significant improvements in burnout and engagement indices coupled with high participant adherence and minimal VR discomfort underline the potential of VR interventions in health care settings. These encouraging findings pave the way for more comprehensive studies, including randomized controlled trials, to further validate and expand upon these results.

KEYWORDS

virtual reality; burnout; mindfulness; health care professionals; mental health; health promotion; educational intervention

Introduction

Background

Burnout among health care workers is a growing concern that affects professionals worldwide. Burnout is characterized by emotional exhaustion, depersonalization, and a diminished sense of personal accomplishment [1], and it extends beyond transient workplace stress, potentially undermines patient care quality, increases the rate of errors, creates a negative work climate, and contributes to health care costs [1-3]. The prevalence of burnout varies considerably, with a scoping review during the COVID-19 pandemic reporting rates of 4.3% to 90.4% among health care workers, reflecting the significant mental burden and high levels of stress and burnout experienced by frontline health care workers during this period [4]. This review highlighted multiple factors associated with increases or decreases in burnout, including demographic characteristics, psychological conditions, social factors, work organization, and direct COVID-19-related impacts, providing valuable insights for policy makers and health care managers [4].

The COVID-19 pandemic has notably worsened this panorama, causing unprecedented spikes in burnout rates. Data from Spain [5] revealed an increase from 10% before the pandemic to a staggering 50% during the pandemic, with a marked rise in emotional exhaustion and depersonalization, and a decline in personal accomplishment among primary care physicians.

Economically, burnout contributes to substantial costs in the health care system, with estimates in the United States indicating a US \$979 million annual burden related to turnover and reduced clinical hours among primary care physicians alone [6,7]. To deal with this issue, the World Health Organization has underscored the importance of psychosocial interventions, including mindfulness and cognitive behavioral strategies, to enhance mental health and stress management in the workplace [8].

Contemporary research supports mindfulness as an effective intervention against burnout [9,10]. This practice, originally encapsulated by Kabat-Zinn's [11] conceptualization as an intentional nonjudgmental focus on the present experience, is gaining recognition as a cornerstone in the arsenal against burnout among medical professionals [12]. The implementation of mindfulness is corroborated by evidence indicating its significant contribution to bolstering emotional resilience, fostering effective communication, and reinforcing collaborative dynamics in the often high-pressure clinical environment [13-15].

Integration of Mindfulness Practices in Health Care Through Virtual Reality Technology

With the integration of technology into health care, virtual reality (VR) offers a novel platform for mindfulness training. By simulating controlled environments, VR can deepen

mindfulness practices, potentially surpassing traditional methods in improving mood, sleep quality, and cognitive focus [16]. The immersive experiences of VR are known to increase knowledge retention and engagement, making educational interventions more effective [17-22].

The application of VR to mindfulness training presents a unique opportunity for health care professionals to cultivate skills for managing stressors inherent to their profession. Empirical evidence suggests that VR-based mindfulness can yield significant benefits for emotional regulation and stress reduction, thus improving the well-being of health care providers [23-26].

Study Objective and Hypothesis

The objective of this pilot study was to evaluate the immediate impact of an 8-week VR educational program on burnout and work engagement among health care professionals. The study measured changes in the levels of emotional exhaustion, depersonalization, and personal accomplishment as characterized by the Maslach Burnout Inventory (MBI), along with the dimensions of vigor, dedication, and absorption as depicted by the Utrecht Work Engagement Scale (UWES).

The study was guided by 2 hypotheses. The null hypothesis (H0) proposed that the VR educational program would not result in significant changes in burnout or work engagement levels, and any variations could be attributed to random fluctuation rather than the intervention's effect. Conversely, the alternative hypothesis (H1) suggested that the VR program would lead to significant improvements in these measures, reflecting a direct positive impact of the intervention on the professional well-being of participants.

While burnout is recognized as a multifaceted syndrome influenced by a variety of factors, the project posited that a targeted VR program focusing on mindfulness and emotional management might enhance resilience among health care professionals. This resilience, in turn, could modify their perception and coping mechanisms, equipping them with effective strategies to counteract work-related stress. The insights gained from this study are expected to contribute to the development of innovative and more personalized interventions that are tailored to the needs of health care workers [25,26].

Methods

Study Design

In this prospective interventional pilot study, a nonrandomized pre-post intervention design was used to explore the preliminary effects of a mindfulness-based VR educational program in health care professionals.

Participants and Setting

This pilot study enrolled 90 health care professionals, representing a broad range of specialties in the health care sector. The demographic profile of the 83 participants who completed

the program revealed an average age of 46.39 years and a mean professional tenure of 17.57 years. The cohort was predominantly female, with only 7 male participants, reflecting the sex distribution that is common in these centers. The detailed breakdown of professional roles within the cohort is presented in the Results section.

Selection and Enrollment

Recruitment

Recruitment for the study was conducted via an open invitation across 3 health care centers, and the study targeted a diverse group of professionals, including nurses, physicians, administrative staff, nursing assistants, occupational therapists, social workers, psychologists, pediatricians, dentists, and ward assistants.

The first, second, and third centers have been identified in this study as CAP-A, CAP-B, and CSSC, respectively. Informative sessions were held in each center during the recruitment of each group owing to different time periods. During these sessions, all professionals were able to ask questions about VR and the program, and later decide if they were interested in participating. If interested, they were required to send an email to our team to be evaluated for inclusion.

The absence of a control group in this study was a strategic choice, which was influenced by the exploratory nature of the pilot study and resource limitations. This choice and its implications are further discussed in the Limitations subsection. The study's pre-post design without a control group necessitated a sample size that was feasible within the available resources and anticipated participant availability.

Inclusion and Withdrawal Criteria

Health care professionals who were currently employed in the study centers, older than 18 years, and able to commit to the program's full duration were considered for inclusion. Informed consent was required, along with a commitment to complete all questionnaires. Participants were excluded if they had participated in a similar program or received specific training in burnout prevention within the last 12 months, had a long-term absence from work or any situation that prevented regular attendance during the study, or had vertigo, epilepsy, or significant visual/auditory disabilities that precluded the use of VR glasses. Withdrawal from the study was considered when participants had significant intolerance to VR equipment or were absent for more than two sessions. To facilitate participation and minimize dropout, participants were allowed a 2-week grace period after the program to cover any missed sessions.

Sequential Enrollment, Center Allocation, and Attrition

Enrollment and participation were conducted in sequential phases to accommodate the limited number of VR headsets, with only 2 headsets available for the entire study. The initial enrollment occurred at the first center (CAP-A) in February 2022, with 29 participants included and then divided randomly into 3 groups for logistic reasons. The groups completed the program at different times throughout the year, with the final group concluding in December 2022.

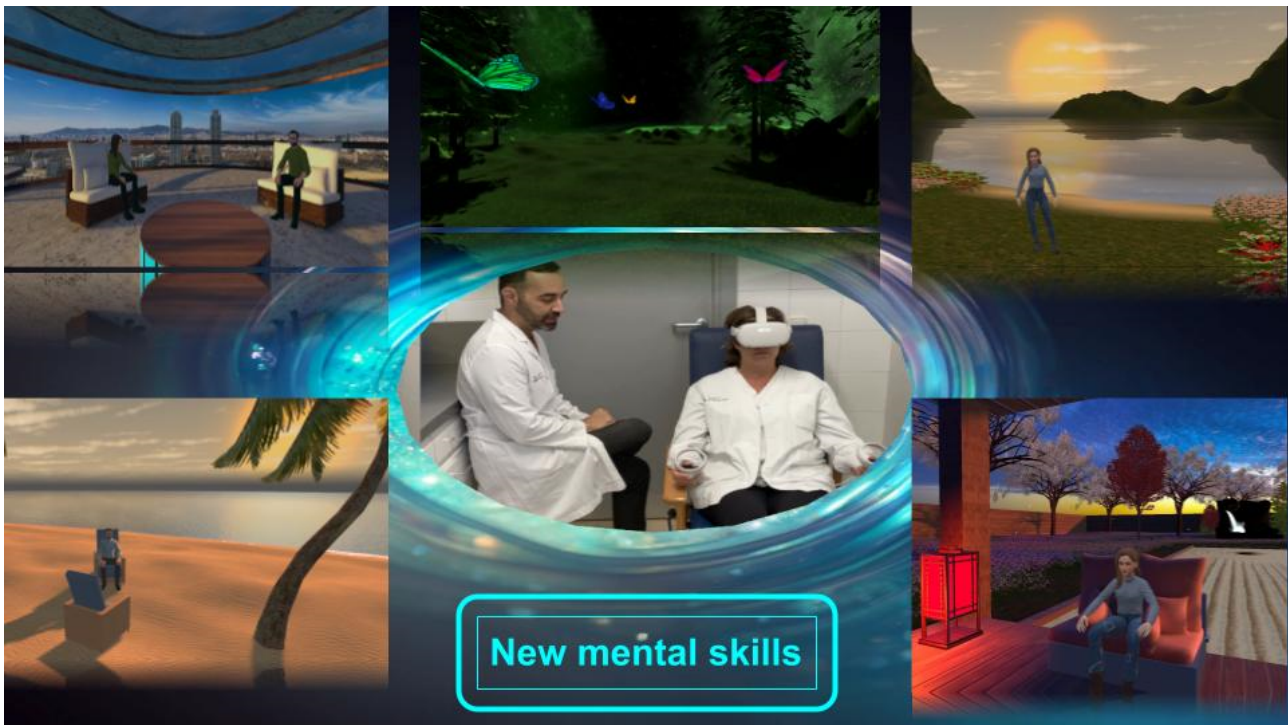
Building on the lessons learned from the initial phase regarding resource utilization and scheduling, the process was refined for subsequent enrollments. In 2023, a more streamlined approach was adopted at the next 2 centers, where all participants were enrolled in a single group per center to simplify logistics. Recruitment for the study was conducted simultaneously at both centers in January and February 2023. At CSSC, 41 participants were included, with 36 participants successfully completing the program between February and April 2023. At CAP-B, 20 participants were initially enrolled, with 14 participants completing the program in April and a small additional group of 4 participants completing the program in October 2023.

Instruments

The intervention was delivered through Meta Quest 2 VR headsets (Meta Platforms, Inc), which were chosen for their cable-free stand-alone functionality and high-quality audiovisual output. The headsets feature hand tracking capabilities that were used in the program to enhance immersion by visualizing users' hands in VR and allowing simple selection of sessions via the menu. The program was developed between April 2021 and January 2022 following a methodical approach based on bibliographic review and guided by the expertise of author NM. It integrated mindfulness and emotional management techniques, which are well-established methods for reducing burnout and enhancing work engagement, and are particularly beneficial in health care settings [9-26]. The VR sessions were developed by author JFC. VR technology was integrated with the author's clinical expertise in mindfulness to create a dynamic learning environment. Unity (Unity Technologies) and Blender (Blender Foundation) were used to construct 3D animations that visually represent and illustrate mindfulness and emotion management techniques. These animations serve as immersive educational tools within VR environments, enhancing the learning experience beyond traditional relaxation sessions. Moran Bueno, who specializes in mindfulness at the University of Barcelona, ensured that the content was scientifically accurate and pedagogically effective. The development process involved iterative feedback from health care professionals, aiming to refine the program's educational impact and comfort. The VR environments were specifically crafted for passive educational engagement, allowing participants to immerse in the program without the need for active interaction or physical movement and thus enhancing the learning experience in a safe and user-friendly manner. The VR program allowed for a more engaging and potentially more impactful learning experience by placing participants in various virtual environments that can enhance the absorption of the techniques taught.

The VR sessions immersed participants in various carefully designed settings, such as a serene beach, calm lake, and peaceful Zen garden. Ambient sounds corresponding to each environment, like the soothing lapping of waves, were incorporated to deepen the sensory experience. This auditory enhancement, in tandem with visual elements, augmented the overall educational and immersive quality for the users. The integration of these sensory aspects aimed to create an optimal learning environment for engaging with the mindfulness and emotional management content (Figure 1).

Figure 1. Some of the virtual reality environments of the educational program. Displayed images from the top middle in clockwise direction are butterflies in a garden, a serene bay, a zen garden, a tropical beach, and a terrace with panoramic views of Barcelona. At the center is an image of a supervised session in progress.



VR Considerations

Although VR is a technological tool with minimal risk, the use of VR headsets, especially for extended periods, can occasionally lead to side effects, such as cybersickness, eye strain, emotional reactions, and physical danger, in some individuals [20,27-30]. These potential effects were carefully considered in the design of the intervention to minimize any adverse outcomes. The potential side effects are as follows [27,30]:

- **Cybersickness:** Symptoms include nausea, balance issues, disorientation, headache, eye strain, and general fatigue, which tend to dissipate shortly after the discontinuation of VR use.
- **Eye strain:** Eye discomfort may occur with extended VR use, although such instances are uncommon given the brevity of typical exposure times in a controlled research setting.
- **Intense emotional reactions:** The compelling realism of VR and the emotion-related content can provoke emotional responses, requiring monitoring.
- **Physical danger:** While rare in a controlled environment, there is a potential risk of physical injury due to loss of spatial awareness while immersed in VR. This includes the possibility of tripping, bumping into objects, or other accidents, particularly if the physical space is not adequately prepared for VR activities.

Mitigation Measures

The project development incorporated strategic measures to address human factors and ergonomic considerations, aiming to minimize VR-induced side effects. These measures, which aligned with current guidelines and best practices, were

meticulously designed to ensure the safety and efficacy of the VR intervention [27-30]. The design aspects are as follows:

- **Session duration:** VR sessions are capped at 10-13 minutes, reducing the risk of cybersickness and visual fatigue [27].
- **Static interaction:** Design of the VR experience for seated participants (minimal requirement for movement) reduces the risks of nausea and physical activity in VR [28,29].
- **Hand tracking:** Incorporation of hand tracking technology allows participants to maintain a sense of agency and immersion in the VR environment without necessitating complex interactions [28,29].
- **Optimization of the VR content:** VR content is carefully designed to avoid overly intense stimuli and to support user comfort. Adjustments to lighting, motion, and frame rates are considered to prevent disorientation and discomfort [27,30].
- **Stress relief features:** Elements, such as biophilic designs, soft colors, and calming music within the VR environment, are incorporated to create a restorative virtual space for users [27].
- **Monitoring and support:** Continuous observation during VR exposure and immediate follow-up after VR exposure permits the research team to identify and mitigate any adverse effects. Participants are advised on headset adjustment and encouraged to take breaks as needed [27,29].
- **User training:** Prior to the initiation of the VR educational program, participants need to undergo a training session focused on VR utilization. This session includes instructions on the proper adjustment of the VR headset, acclimatization to immersive experiences, navigation of the VR interface, and response to potential side effects. The aim is to foster participant independence in managing the VR system and to ensure comfort during use [29].

This approach not only aids in minimizing potential motion-induced discomfort but also ensures a consistent and comfortable experience for all participants. During the course of the research, no VR-related side effects were observed. The only concern reported by a small subset of participants ($n=7$) was discomfort attributed to the weight of the headset. In most instances, this was alleviated, at least partially, by readjusting the headset. Regular check-ins were conducted after the sessions to monitor any adverse effects, and guidance was provided to participants on taking breaks or adjusting the headset position as needed, which further contributed to the positive reception and comfort of the intervention.

Procedure

The program lasted for 8 weeks. A calendar was created, and each participant was assigned a specific day and time every week for their 13-minute VR session. Each session was designed with a clear structure, consisting of 3 phases: preparation, VR experience, and cleanup. In order to ensure a secure and efficient implementation of the program, the sessions were conducted under the supervision of one of the researchers. During the preparation phase, participants were welcomed and assisted with the VR headset adjustment. The role of the researcher included monitoring the implementation for consistency, managing any technical issues, and ensuring that the VR equipment was used safely and effectively.

A key advantage of this VR program is that it constitutes a fully self-contained system. The VR content was directly uploaded to the headsets, thereby eliminating dependency on internet connectivity, an essential feature for accommodating health care professionals operating in environments where internet access may be limited or nonexistent.

Content Overview

Over the sessions, participants engaged with content from the following primary areas:

- **Mindfulness training:** In these sessions, exercises are focused on breath and body scanning, aiming to ground participants in the present moment. By maintaining an attitude of acceptance and nonjudgment, these sessions aim to teach how to foster mental tranquility.
- **Emotional regulation:** In these sessions, participants are introduced to techniques designed to address and manage intense emotions. Instead of suppressing or avoiding discomforting feelings, participants are encouraged to approach them with openness and curiosity, potentially deriving insights and understanding from their observations.
- **Self-compassion:** This area underscores the importance of treating oneself with kindness, especially during challenging times. Recognizing and minimizing the influence of one's inner critic is crucial. Participants are taught to treat themselves with the same warmth and understanding they would extend to a close friend or loved one, promoting a balanced self-view.

Variables

The study evaluated the intervention's impact using demographic and psychometric assessments. Demographic data

collected included age, sex, professional category, and tenure, to understand sample characteristics and control for confounding factors. Psychometric evaluation was performed with 2 established tools: MBI and UWES. These 2 scales were administered on paper before the commencement of the first session and after the conclusion of the last session. Both scales score their 3 subdimensions on a Likert scale from 0 (never) to 6 (daily).

The MBI is an established instrument for assessing burnout in health care settings, and it uses 3 subscales, namely, emotional exhaustion, depersonalization, and personal accomplishment, to capture burnout dimensions. Its high reliability has been confirmed with Cronbach α coefficients ranging from 0.71 to 0.90 in the Spanish health care context, validating its use for this study [31-36].

The subscales are interpreted as follows [36]:

- **Emotional exhaustion:** A score of ≥ 27 indicates a high level of burnout, 19-26 indicates a moderate level of burnout, and < 19 indicates a low level of burnout.
- **Depersonalization:** A score of > 10 indicates a high degree of depersonalization, 6-9 indicates a moderate degree of depersonalization, and < 6 indicates a low degree of depersonalization.
- **Personal accomplishment:** A score of 0-30 suggests a low degree of personal accomplishment, 34-39 suggests a moderate degree of personal accomplishment, and > 40 suggests a high degree of personal accomplishment.

The UWES is a questionnaire that measures work engagement through 3 aspects: vigor, dedication, and absorption, which are defined by high energy, a sense of significance, and deep involvement in work, respectively. Scores on the UWES are calculated as mean values across the items for each dimension. Based on these mean scores, engagement levels are categorized into 5 distinct groups: very low, low, medium, high, and very high. This categorization allows for a nuanced understanding of work engagement among participants. The UWES shows robust psychometric properties for Spanish medical professionals, with a Cronbach α total reliability score of 0.93 and strong subscale consistencies. It has been proven to be effective for correlating work engagement with health outcomes and job stress, making it a pertinent choice for assessing the positive occupational states in the study [37-40].

Ethical Considerations

This study was conducted in compliance with the principles outlined in the Declaration of Helsinki (1964) for research involving human subjects, as evaluated and approved by the Badalona Serveis Assistencials' Research Committee and the Jordi Gol i Gurina Foundation Ethics Committee (approval number: 21/280-P). The committees conducted an ethical review of the project, which included consideration of participant confidentiality, informed consent, and potential risks to participants.

Statistical Analysis

Data Anonymization and Blinding

To protect participant confidentiality while ensuring data integrity, each data set was pseudoanonymized with an identifier code. This measure allowed for an individual response to be tracked without revealing personal information. The principal investigator was the sole individual with access to the decryption key, thus reinforcing the partial blinding of research staff and minimizing potential biases. Statistical analysis was performed with DATAtab (DATAtab e.U.) and SPSS Version 27 (IBM Corp).

Normality Tests

The Shapiro-Wilk test was used to determine the distribution of each variable, a necessary step to guide the selection of appropriate statistical tests for the subsequent analyses.

Inferential Statistical Analysis and Hypothesis Testing

Following the descriptive summary of the data, inferential statistical analyses were conducted to test the study's hypothesis that the VR educational program would lead to significant changes in burnout and work engagement scores. The paired *t* test was applied to normally distributed variables to determine if the mean differences in scores before and after the intervention were statistically significant. For data that did not meet the criteria for normal distribution, the Wilcoxon signed-rank test was used to assess median score differences. All tests set the significance threshold at $P < .05$.

Table 1. Demographic profile of the study participants.

Professional category	Participants, n	Age (years), mean	Age (years), range	Sex (female/male), n	Tenure (years), mean	Tenure (years), range
Nurses	30	44.93	29-56	27/3	18.90	2-34
Physicians	15	50.80	39-63	12/3	15.33	2-32
Administrative staff	13	48.92	35-59	12/1	16.69	1-36
Nursing assistants	7	45.43	27-58	7/0	17.43	1-29
Occupational therapists	7	46.43	41-57	7/0	24.86	18-42
Social workers	3	41.33	40-43	3/0	7.33	1-16
Psychologists	3	39.33	28-47	3/0	17.67	15-21
Pediatricians	2	36.00	33-39	2/0	7.25	3.5-11
Dentists	2	45.00	41-49	2/0	19.00	13-25
Ward assistants	1	57.00	57	1/0	21.00	21
Overall	83	46.39	27-63	76/7	17.57	1-42

Descriptive Statistics

Upon establishing the distribution characteristics of the data set, descriptive statistics summarized the data for the 83

Results

Demographics

Attrition resulted in a final sample of 83 participants who completed the intervention (5 dropouts from CSSC and 2 from CAP-B; CAP-A retained all its participants). The study achieved a high participation rate of 92% (83/90). Attrition was due to personal circumstances not related to the VR system. Specifically, 1 participant was on maternity leave, 3 were on sick leave, and 3 cited time constraints as the reason for withdrawal. Notably, there were no dropouts attributed to discomfort or adverse reactions to the VR technology.

The demographic characteristics of the participants are summarized in [Table 1](#). The final sample consisted of 83 health care professionals with an average age of 46.39 (range 27-63) years. The cohort included 30 nurses, 15 physicians, and individuals with various other roles such as administrative staff and nursing assistants. Female participants represented the majority of the sample, with 76 female participants compared to 7 male participants. The mean tenure was 17.57 years, with individual tenures ranging from 1 to 42 years, reflecting a wide range of professional experience among the participants. These demographic data offer a comprehensive overview of the study sample, highlighting the diversity in age, professional role, and experience within the health care setting.

participants who completed the VR educational program. The analysis provided an initial overview of the results ([Table 2](#)).

Table 2. Descriptive statistics of the Maslach Burnout Inventory and Utrecht Work Engagement Scale items among the 83 study participants.

Variable	Mean	Median	SD	Minimum	Maximum
Emotional exhaustion					
Preintervention	22.67	21	10.88	2	51
Postintervention	17.07	17	9.00	0	42
Depersonalization					
Preintervention	10.04	10	5.07	0	24
Postintervention	7.37	7	4.34	0	20
Personal accomplishment					
Preintervention	29.72	30	8.64	1	47
Postintervention	33.08	34	6.70	17	46
Vigor					
Preintervention	22.90	23	5.91	8	35
Postintervention	24.41	24	5.65	8	36
Dedication					
Preintervention	18.72	19	6.43	6	30
Postintervention	20.36	22	5.88	8	30
Absorption					
Preintervention	19.86	21	6.58	6	32
Postintervention	21.71	23	6.39	6	35

Efficacy of the VR Educational Program

Descriptive Analysis

An analysis of MBI and UWES scores after the VR program reflects a potential impact on participants' professional well-being. [Multimedia Appendix 1](#) presents data indicating a dual effect. There was a reduction in burnout as evidenced by lower emotional exhaustion and depersonalization scores, alongside increased feelings of personal accomplishment. Simultaneously, elevated vigor, dedication, and absorption scores indicated augmented work engagement following the VR intervention.

Following the descriptive analysis, [Table 3](#) provides a detailed breakdown of the distribution of burnout levels among participants both before and after the intervention. The table categorizes participants into low, moderate, and high levels of burnout for each of the following 3 MBI subscales: emotional exhaustion, depersonalization, and personal accomplishment. It presents these categories in both percentage and actual number of participants, offering a clear perspective on the shift in burnout levels after the intervention among the 83 health care professionals involved in the study.

Table 3. Distribution of burnout levels among the 83 study participants before and after the intervention.

Variable	High burnout, n (%)	Moderate burnout, n (%)	Low burnout, n (%)
Emotional exhaustion			
Preintervention	27 (33)	24 (29)	32 (39)
Postintervention	10 (12)	20 (24)	53 (64)
Depersonalization			
Preintervention	45 (54)	21 (25)	17 (21)
Postintervention	21 (25)	34 (41)	28 (34)
Personal accomplishment			
Preintervention	44 (53)	26 (31)	13 (16)
Postintervention	29 (35)	40 (48)	14 (17)

Statistical Comparisons and Significance

Shapiro-Wilk tests were used to determine the normality of all variables. Emotional exhaustion, depersonalization, personal accomplishment, and vigor, which followed a normal distribution, were analyzed using *t* tests. The nonnormally distributed variables dedication and absorption were analyzed using the Wilcoxon test. Additionally, effect sizes were calculated using Cohen *d* for normally distributed data and Cohen *r* for nonnormally distributed data to quantify the magnitude of observed changes.

Correlation and Effect Size Assessments

Correlation assessments were integral to the analysis in order to evaluate relationships between preintervention and postintervention scores. The Pearson correlation was applied to normally distributed data, and the Spearman correlation was used for nonnormally distributed data, with findings reported in Tables 4 and 5. The Cohen *d* and *r* have been provided to reflect the effect sizes and assess the strength of differences, with statistically significant changes ($P < .05$) in all variables.

Table 4. Summary of preintervention and postintervention analysis results for normally distributed variables.

Variable	Preintervention result, mean (SD)	Postintervention result, mean (SD)	<i>t</i> test <i>t</i> (<i>df</i>)	<i>P</i> value (2-tailed)	Effect size, Cohen <i>d</i>	Pearson <i>r</i>	Pearson <i>P</i>
Emotional exhaustion	22.67 (10.88)	17.07 (9.00)	5.58 (82)	<.001	0.61	0.59	<.001
Depersonalization	10.04 (5.07)	7.37 (4.34)	4.67 (82)	<.001	0.51	0.40	<.001
Personal accomplishment	29.72 (8.64)	33.08 (6.70)	-3.62 (82)	<.001	0.40	0.41	<.001
Vigor	22.65 (5.98)	24.66 (5.50)	-3.77 (82)	<.001	0.41	0.64	<.001

Table 5. Summary of preintervention and postintervention analysis results for nonnormally distributed variables.

Variable	Preintervention result, median (IQR)	Postintervention result, median (IQR)	Wilcoxon test			Effect size, Cohen <i>r</i>	Spearman <i>r</i>	Spearman <i>P</i>
			<i>W</i>	<i>z</i>	<i>P</i> value (2-tailed)			
Dedication	19 (12)	22 (8)	580	-3.63	<.001	0.41	0.73	<.001
Absorption	20 (10)	23 (9.5)	785.5	-3.52	<.001	0.40	0.67	<.001

Epidemiologic Factors

Spearman correlation analysis was employed to explore relationships between age, tenure, and the main study variables, and it revealed no significant correlations. Similarly, point biserial correlation analysis indicated no significant correlations between sex and the study variables both before and after the intervention.

The influence of professional categories on questionnaire outcomes was assessed using η^2 values (Table 6). The η^2 values ranged from 0.01 to 0.24 and indicated the proportion of variance in each measure that can be attributed to the professional category. Higher η^2 values, such as those for

preintervention depersonalization, suggested a more significant variance related to the professional category, while other measures exhibited a lower degree of variance due to professional categorization, reflecting a range of impacts across different professional categories.

The ANOVA analysis provided deeper insights into the intervention's impact, examining changes in the MBI and UWES scores. This analysis encompassed overall changes and variations across different professional categories. Detailed statistical outcomes, including sums of squares, mean squares, *F* values, and *P* values, are presented in Table 7, highlighting the statistical significance of the observed changes.

Table 6. Maslach Burnout Inventory and Utrecht Work Engagement Scale data across different professional categories.

Professional category	Emotional exhaustion, mean (SD)		Depersonalization, mean (SD)		Personal accomplishment, mean (SD)		Vigor, mean (SD)		Dedication, mean (SD)		Absorption, mean (SD)	
	Pre ^a	Post ^b	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Nurses	20.37 (8.78)	18.77 (8.22)	9.97 (4.43)	8.00 (4.10)	30.03 (8.26)	33.73 (7.23)	21.90 (6.83)	23.37 (5.84)	18.57 (6.78)	20.23 (5.66)	19.40 (7.37)	21.37 (6.35)
Physicians	26.13 (12.70)	19.93 (9.90)	10.13 (4.66)	7.80 (4.72)	29.40 (5.59)	31.53 (7.62)	21.60 (5.33)	24.60 (5.26)	18.33 (6.20)	21.60 (5.53)	20.80 (6.11)	24.07 (4.38)
Administrative staff	22.00 (7.97)	15.77 (9.36)	13.15 (3.93)	8.00 (4.81)	27.23 (8.63)	31.23 (5.95)	24.00 (4.93)	27.08 (4.96)	16.38 (6.46)	18.69 (6.13)	19.77 (6.31)	22.31 (7.09)
Nursing assistants	22.43 (10.50)	16.00 (12.49)	11.00 (4.90)	7.71 (4.54)	25.29 (14.28)	32.00 (8.70)	23.29 (6.42)	26.14 (6.15)	20.43 (7.28)	21.43 (6.85)	19.00 (7.79)	22.14 (7.65)
Occupational therapists	17.86 (12.42)	10.57 (4.08)	9.14 (7.36)	4.57 (2.23)	33.43 (6.75)	35.43 (2.64)	25.00 (6.08)	24.57 (4.72)	20.43 (7.74)	21.29 (4.75)	19.00 (6.93)	19.57 (7.59)
Psychologists	36.33 (4.16)	14.33 (6.03)	3.00 (3.61)	3.33 (1.53)	27.67 (10.21)	35.67 (5.03)	22.33 (2.89)	26.67 (1.53)	21.67 (2.52)	22.00 (1.00)	21.33 (9.81)	23.33 (6.35)
Social workers	15.33 (8.08)	11.67 (6.81)	2.67 (2.52)	4.33 (4.51)	35.67 (12.70)	33.33 (8.14)	19.67 (7.57)	23.00 (5.57)	18.67 (10.21)	20.33 (8.08)	20.33 (8.14)	22.33 (6.43)
Pediatricians	43.50 (10.61)	27.00 (5.66)	13.50 (2.12)	11.50 (7.78)	29.00 (5.66)	33.00 (4.24)	23.50 (6.36)	17.00 (4.24)	16.00 (5.66)	12.50 (4.95)	18.00 (5.66)	17.00 (2.83)
Ward assistants	26.50 (20.51)	12.50 (6.36)	10.50 (6.36)	5.50 (3.54)	38.00 (11.31)	38.00 (4.24)	25.00 (9.90)	28.00 (4.24)	23.00 (7.07)	21.50 (4.95)	18.50 (7.78)	21.00 (7.07)
Dentists	16.00 (N/A ^c)	7.00 (N/A)	5.00 (N/A)	8.00 (N/A)	36.00 (N/A)	34.00 (N/A)	26.00 (N/A)	31.00 (N/A)	19.00 (N/A)	27.00 (N/A)	17.00 (N/A)	21.00 (N/A)
η^d	0.47	0.39	0.49	0.35	0.32	0.24	0.23	0.37	0.23	0.31	0.12	0.24
η^{2d}	0.22	0.15	0.24	0.13	0.1	0.06	0.05	0.14	0.05	0.09	0.01	0.06

^aPre: preintervention.^bPost: postintervention.^cN/A: not applicable.^d η and η^2 values indicate the variance due to professional categorization.

Table 7. ANOVA results for preintervention and postintervention measures and professional categories.

Variable	Sum of squares	Degrees of freedom (<i>df</i>)	Mean squares	<i>F</i>	<i>P</i> value
Emotional exhaustion					
Preintervention/postintervention	1302.56	1	1302.56	37.07	<.001
Professional category	2294.19	9	254.91	1.75	.09
A×B	861.83	9	95.76	2.73	.008
Depersonalization					
Preintervention/postintervention	294.22	1	294.22	21.89	<.001
Professional category	567.48	9	63.05	2.33	.02
A×B	126.04	9	14.00	1.04	.42
Personal accomplishment					
Preintervention/postintervention	468.92	1	468.92	12.37	.001
Professional category	656.22	9	72.91	0.86	.57
A×B	168.51	9	18.72	0.49	.87
Vigor					
Preintervention/postintervention	168.01	1	168.01	14.59	<.001
Professional category	360.04	9	40.00	0.72	.69
A×B	131.10	9	14.57	1.27	.27
Dedication					
Preintervention/postintervention	128.41	1	128.41	13.11	.001
Professional category	358.90	9	39.88	0.58	.81
A×B	84.81	9	9.42	0.96	.48
Absorption					
Preintervention/postintervention	208.41	1	208.41	12.78	.001
Professional category	194.98	9	21.66	0.29	.98
A×B	34.49	9	3.83	0.24	.99

Discussion

Principal Findings

In this pilot study, we implemented an 8-week VR educational program focused on mindfulness and emotional management for health care professionals. The results suggest that the program can positively affect burnout symptoms and work engagement in this group. This inference is drawn from the significant reductions observed in burnout symptoms and enhancements in work engagement metrics after the intervention (Tables 2-5 and Multimedia Appendix 1). Complementing the observed reductions in burnout symptoms, the VR educational program also appears to have positively influenced work engagement (Tables 4 and 5). These shifts are especially prominent in the dimensions of dedication and absorption, highlighting the VR program's potential in enhancing aspects of work engagement that relate to a sense of significance and deep involvement in work.

The reduction in score variability after the intervention, as shown in Tables 4 and 5, implies a standardized effectiveness of the VR program in mitigating burnout symptoms. This

uniform decrease in scores like emotional exhaustion and depersonalization scores highlights the VR program's consistent impact across participants. The effect sizes, as analyzed from Tables 4 and 5, reveal a more significant impact of the VR intervention in reducing negative burnout aspects, particularly emotional exhaustion and depersonalization, than in enhancing positive work attributes.

Differential Impact Across Professional Categories

The VR program's effects varied among health care roles, as seen in the η^2 values in Table 6. High variability in emotional exhaustion and depersonalization suggests that roles like psychologists and pediatricians might be more vulnerable to certain burnout aspects. Conversely, measures like vigor and absorption showed more uniform responses across roles. The ANOVA analysis revealed significant variation for emotional exhaustion across categories, emphasizing the need for tailored interventions in health care (Table 7). However, the findings should be approached cautiously due to the limited sample size in some categories, needing further research for conclusive results.

Comparison With Prior Work

The improvement in positive occupational states is a key outcome, given the critical role of engagement in the overall well-being and job performance of health care professionals [41]. The successful application of VR in mindfulness and emotional management training is consistent with existing literature [12,13], underscoring its potential as a vital psychosocial intervention tool in health care settings. This aligns with the findings of Lee and Cha [42], indicating the need for refined VR strategies to balance reducing burnout and boosting work engagement in health care.

Strengths and Implications

This pilot study has significant strengths and yields insights with practical implications for addressing burnout in health care professionals. The low dropout rate reinforces user engagement and the potential of VR as a sustainable educational tool, as observed in other research efforts [14-16,43]. The adherence rate of 92% (83/90) along with minimal reports of discomfort from VR use demonstrates its viability in a clinical setting. These factors are encouraging, especially considering the need for ergonomic consideration highlighted by the ease of resolving discomfort with simple adjustments.

The study's VR intervention was designed with a focus on user comfort, drawing from the mitigation strategies outlined in the VR Considerations subsection of the Methods section. This careful design likely contributed to the positive reception and ease of use reported by participants, underscoring the potential of VR in supporting World Health Organization-endorsed strategies for stress management in clinical environments [8].

Limitations

The promising results obtained in this pilot study must be viewed within the context of some methodological constraints. First, the lack of a control group in the study design precludes a definitive conclusion regarding the causality of observed changes, suggesting that further studies with control groups are necessary to corroborate the VR program's effectiveness. Second, the reliance on convenience sampling poses a risk for selection bias, and future studies may benefit from randomized sampling to ensure broader applicability of the results. Third, the study's participant demographic, with a significant underrepresentation of male participants, reflects the female majority typical in health care settings, particularly in our primary care centers where approximately 79.6% of our health care workers are female according to data provided by our

Human Resources department in November 2023. This gender imbalance limits the generalizability of our findings across all genders. Future research should aim to include a more balanced gender distribution when possible, exploring if VR educational programs have differential effects on various demographic groups. Fourth, the sample size, which is appropriate for a preliminary exploration into VR-based interventions, is nonetheless insufficient for establishing definitive efficacy, underscoring the need for larger more representative studies. Resource-related phased implementation may have introduced variability in delivery, which was mitigated in later stages but could have affected initial participant experience. Future studies should increase the sample size to provide more robust evidence of efficacy. It is also recommended to standardize the implementation process across all phases to minimize variability and improve the reliability of the results.

Conclusions

This pilot study provides initial indications that an 8-week VR-based educational program may positively influence burnout and work engagement among health care professionals. Our findings suggest a reduction in burnout symptoms, as measured by the MBI, and an increase in work engagement, as indicated by the UWES. While the data hint at VR's promise for reducing burnout symptoms and fostering work engagement, the results should be viewed as preliminary. The interpretive value of the findings is limited by the sample size and the absence of a control group, despite the application of rigorous statistical analyses to assess the intervention's impact.

To enhance future assessments and maintain equitable access to potential benefits, subsequent research could adopt a crossover study design. Such a design would involve randomizing participants into initial control and intervention groups, with a subsequent exchange of roles following a predetermined washout period. This methodological approach would allow for a comprehensive evaluation of the VR program's impact by ensuring that each participant acts as their own control, thereby reinforcing the strength of the evidence gathered while ensuring access to the intervention.

This study contributes to the literature on the use of VR technology in education and health care, highlighting the potential of digital health interventions in disease prevention and health promotion, and emphasizing the importance of prioritizing the well-being of health care professionals as a main requirement for the survival of the health care system.

Acknowledgments

The authors would like to express their appreciation to the management and directive board of Badalona Serveis Assistencials for their invaluable support and trust in this research project. This study was self-funded by Badalona Serveis Assistencials and conducted independently without external funding sources influencing the methodology, analysis, or outcomes. The research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

The authors also extend their gratitude to the participants of the study for their willingness to take part in the virtual reality educational program and for their contribution to the advancement of knowledge in this field. The authors would like to acknowledge the efforts of the research team for the contributions to the study design, data collection, and analysis.

In refining the format and clarity of our manuscript, we used artificial intelligence–based tools for text editing assistance. It is important to note that these tools were used solely for improving the presentation of our content, with all original ideation and content creation carried out by the human authors. Every artificial intelligence–assisted edit was subject to thorough review and final adaptation by our team to ensure accuracy and integrity of the manuscript.

The authors would like to thank the anonymous reviewers for their valuable feedback, which helped to strengthen the quality of this publication.

All authors declare that they had insufficient or no funding to support open access publication of this manuscript, including from affiliated organizations or institutions, funding agencies, or other organizations. JMIR Publications provided article processing fee (APF) support for the publication of this article.

Data Availability

The data sets generated or analyzed during this study are available from the corresponding author upon reasonable request.

Authors' Contributions

JFC led the development of the study's software, provided technical support for the virtual reality sessions, was responsible for the data curation and project administration, drafted the initial manuscript, and supervised all data collection phases. NM co-conceptualized the study, developed the study's theoretical framework, was responsible for the audio creation for the sessions, and reviewed and edited the manuscript. CGM, LJCH, and FRCC contributed to the supervision of the sessions and participated in data collection, ensuring the integrity of the data collection process. MJC conducted the formal analysis, played a significant role in interpreting the data, and was a major contributor in writing and revising the manuscript. All authors reviewed and approved the final manuscript for submission and participated in the supervision of the sessions, ensuring rigorous oversight throughout the study.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Mean scores of the Maslach Burnout Inventory and Utrecht Work Engagement Scale.

[[PDF File \(Adobe PDF File\), 94 KB - xr_v1ile55678_app1.pdf](#)]

References

1. Wright T, Mughal F, Babatunde O, Dikomitis L, Mallen C, Helliwell T. Burnout among primary health-care professionals in low- and middle-income countries: systematic review and meta-analysis. *Bull World Health Organ* 2022 Jun 11;100(06):385-401A [[FREE Full text](#)] [doi: [10.2471/blt.22.288300](https://doi.org/10.2471/blt.22.288300)]
2. Hodkinson A, Zhou A, Johnson J, Geraghty K, Riley R, Zhou A, et al. Associations of physician burnout with career engagement and quality of patient care: systematic review and meta-analysis. *BMJ* 2022 Sep 14;378:e070442 [[FREE Full text](#)] [doi: [10.1136/bmj-2022-070442](https://doi.org/10.1136/bmj-2022-070442)] [Medline: [36104064](https://pubmed.ncbi.nlm.nih.gov/36104064/)]
3. García-Iglesias JJ, Gómez-Salgado J, Fagundo-Rivera J, Romero-Martín M, Ortega-Moreno M, Navarro-Abal Y. Factores predictores de los niveles de burnout y work engagement en médicos y enfermeras: una revisión sistemática. *Revista Española Salud Pública* 2022;95:e202104046 [[FREE Full text](#)]
4. Stodolska A, Wójcik G, Barańska I, Kijowska V, Szczerbińska K. Prevalence of burnout among healthcare professionals during the COVID-19 pandemic and associated factors - a scoping review. *Int J Occup Med Environ Health* 2023 Mar 02;36(1):21-58 [[FREE Full text](#)] [doi: [10.13075/ijomh.1896.02007](https://doi.org/10.13075/ijomh.1896.02007)] [Medline: [36727492](https://pubmed.ncbi.nlm.nih.gov/36727492/)]
5. Seda-Gombau G, Montero-Alía J, Moreno-Gabriel E, Torán-Monserrat P. Impact of the COVID-19 Pandemic on Burnout in Primary Care Physicians in Catalonia. *Int J Environ Res Public Health* 2021 Aug 27;18(17):9031 [[FREE Full text](#)] [doi: [10.3390/ijerph18179031](https://doi.org/10.3390/ijerph18179031)] [Medline: [34501618](https://pubmed.ncbi.nlm.nih.gov/34501618/)]
6. Han S, Shanafelt T, Sinsky C, Awad K, Dyrbye L, Fiscus L, et al. Estimating the attributable cost of physician burnout in the United States. *Ann Intern Med* 2019 Jun 04;170(11):784-790. [doi: [10.7326/M18-1422](https://doi.org/10.7326/M18-1422)] [Medline: [31132791](https://pubmed.ncbi.nlm.nih.gov/31132791/)]
7. Sinsky CA, Shanafelt TD, Dyrbye LN, Sabety AH, Carlasare LE, West CP. Health care expenditures attributable to primary care physician overall and burnout-related turnover: a cross-sectional analysis. *Mayo Clin Proc* 2022 Apr;97(4):693-702 [[FREE Full text](#)] [doi: [10.1016/j.mayocp.2021.09.013](https://doi.org/10.1016/j.mayocp.2021.09.013)] [Medline: [35227508](https://pubmed.ncbi.nlm.nih.gov/35227508/)]
8. Guidelines on mental health at work. World Health Organization. 2022. URL: <https://www.who.int/publications/i/item/9789240053052> [accessed 2024-04-17]
9. Lomas T, Medina J, Ivtzan I, Rupprecht S, Eiroa-Orosa F. A systematic review of the impact of mindfulness on the well-being of healthcare professionals. *J Clin Psychol* 2018 Mar;74(3):319-355 [[FREE Full text](#)] [doi: [10.1002/jclp.22515](https://doi.org/10.1002/jclp.22515)] [Medline: [28752554](https://pubmed.ncbi.nlm.nih.gov/28752554/)]

10. Maresca G, Corallo F, Catanese G, Formica C, Lo Buono V. Coping strategies of healthcare professionals with burnout syndrome: a systematic review. *Medicina (Kaunas)* 2022 Feb 21;58(2):327 [FREE Full text] [doi: [10.3390/medicina58020327](https://doi.org/10.3390/medicina58020327)] [Medline: [35208650](https://pubmed.ncbi.nlm.nih.gov/35208650/)]
11. Kabat-Zinn J. *Wherever You Go, There You Are: Mindfulness Meditation in Everyday Life*. New York, NY: Hachette Books; 1994.
12. Selič-Zupančič P, Klemenc-Ketiš Z, Onuk Tement S. The Impact of Psychological Interventions with Elements of Mindfulness on Burnout and Well-Being in Healthcare Professionals: A Systematic Review. *J Multidiscip Healthc* 2023 Jun;16:1821-1831 [FREE Full text] [doi: [10.2147/JMDH.S398552](https://doi.org/10.2147/JMDH.S398552)] [Medline: [37404957](https://pubmed.ncbi.nlm.nih.gov/37404957/)]
13. Cepeda-Lopez A, Solís Domínguez L, Villarreal Zambrano S, Garza-Rodriguez I, Del Valle A, Quiroga-Garza A. A comparative study of well-being, resilience, mindfulness, negative emotions, stress, and burnout among nurses after an online mind-body based intervention during the first COVID-19 pandemic crisis. *Front Psychol* 2023;14:848637 [FREE Full text] [doi: [10.3389/fpsyg.2023.848637](https://doi.org/10.3389/fpsyg.2023.848637)] [Medline: [36993886](https://pubmed.ncbi.nlm.nih.gov/36993886/)]
14. Navarro-Haro M, López-Del-Hoyo Y, Campos D, Linehan M, Hoffman H, García-Palacios A, et al. Meditation experts try Virtual Reality Mindfulness: A pilot study evaluation of the feasibility and acceptability of Virtual Reality to facilitate mindfulness practice in people attending a Mindfulness conference. *PLoS One* 2017;12(11):e0187777 [FREE Full text] [doi: [10.1371/journal.pone.0187777](https://doi.org/10.1371/journal.pone.0187777)] [Medline: [29166665](https://pubmed.ncbi.nlm.nih.gov/29166665/)]
15. Chandrasiri A, Collett J, Fassbender E, De Foe A. A virtual reality approach to mindfulness skills training. *Virtual Reality* 2019 Feb 18;24(1):143-149 [FREE Full text] [doi: [10.1007/s10055-019-00380-2](https://doi.org/10.1007/s10055-019-00380-2)]
16. Ma J, Zhao D, Xu N, Yang J. The effectiveness of immersive virtual reality (VR) based mindfulness training on improvement mental-health in adults: A narrative systematic review. *Explore (NY)* 2023 May;19(3):310-318 [FREE Full text] [doi: [10.1016/j.explore.2022.08.001](https://doi.org/10.1016/j.explore.2022.08.001)] [Medline: [36002363](https://pubmed.ncbi.nlm.nih.gov/36002363/)]
17. Yang H, Cai M, Diao Y, Liu R, Liu L, Xiang Q. How does interactive virtual reality enhance learning outcomes emotional experiences? A structural equation modeling approach. *Front Psychol* 2022;13:1081372 [FREE Full text] [doi: [10.3389/fpsyg.2022.1081372](https://doi.org/10.3389/fpsyg.2022.1081372)] [Medline: [36687987](https://pubmed.ncbi.nlm.nih.gov/36687987/)]
18. Moro C, Štromberga Z, Raikos A, Stirling A. The effectiveness of virtual and augmented reality in health sciences and medical anatomy. *Anat Sci Educ* 2017 Nov;10(6):549-559 [FREE Full text] [doi: [10.1002/ase.1696](https://doi.org/10.1002/ase.1696)] [Medline: [28419750](https://pubmed.ncbi.nlm.nih.gov/28419750/)]
19. Asad MM, Naz A, Churi P, Tahanzadeh MM. Virtual Reality as Pedagogical Tool to Enhance Experiential Learning: A Systematic Literature Review. *Education Research International* 2021 Nov 16;2021:1-17 [FREE Full text] [doi: [10.1155/2021/7061623](https://doi.org/10.1155/2021/7061623)]
20. Barteit S, Lanfermann L, Bärnighausen T, Neuhann F, Beiersmann C. Augmented, mixed, and virtual reality-based head-mounted devices for medical education: systematic review. *JMIR Serious Games* 2021 Jul 08;9(3):e29080 [FREE Full text] [doi: [10.2196/29080](https://doi.org/10.2196/29080)] [Medline: [34255668](https://pubmed.ncbi.nlm.nih.gov/34255668/)]
21. Pascual K, Fredman A, Naum A, Patil C, Sikka N. Should mindfulness for health care workers go virtual? A mindfulness-based intervention using virtual reality and heart rate variability in the emergency department. *Workplace Health Saf* 2023 Apr;71(4):188-194. [doi: [10.1177/21650799221123258](https://doi.org/10.1177/21650799221123258)] [Medline: [36377263](https://pubmed.ncbi.nlm.nih.gov/36377263/)]
22. Meese MM, O'Hagan EC, Chang TP. Healthcare provider stress and virtual reality simulation: a scoping review. *Simul Healthc* 2021 Aug 01;16(4):268-274. [doi: [10.1097/SIH.0000000000000484](https://doi.org/10.1097/SIH.0000000000000484)] [Medline: [32890319](https://pubmed.ncbi.nlm.nih.gov/32890319/)]
23. Lindner P, Miloff A, Hamilton W, Carlbring P. The potential of consumer-targeted virtual reality relaxation applications: descriptive usage, uptake and application performance statistics for a first-generation application. *Front Psychol* 2019;10:132 [FREE Full text] [doi: [10.3389/fpsyg.2019.00132](https://doi.org/10.3389/fpsyg.2019.00132)] [Medline: [30778311](https://pubmed.ncbi.nlm.nih.gov/30778311/)]
24. Oing T, Prescott J. Implementations of virtual reality for anxiety-related disorders: systematic review. *JMIR Serious Games* 2018 Nov 07;6(4):e10965 [FREE Full text] [doi: [10.2196/10965](https://doi.org/10.2196/10965)] [Medline: [30404770](https://pubmed.ncbi.nlm.nih.gov/30404770/)]
25. Navarro-Haro M, Modrego-Alarcón M, Hoffman H, López-Montoyo A, Navarro-Gil M, Montero-Marin J, et al. Evaluation of a mindfulness-based intervention with and without virtual reality dialectical behavior therapy mindfulness skills training for the treatment of generalized anxiety disorder in primary care: a pilot study. *Front Psychol* 2019;10:55 [FREE Full text] [doi: [10.3389/fpsyg.2019.00055](https://doi.org/10.3389/fpsyg.2019.00055)] [Medline: [30745888](https://pubmed.ncbi.nlm.nih.gov/30745888/)]
26. Lu F, Ratnapalan S. Burnout interventions for resident physicians: a scoping review of their content, format, and effectiveness. *Arch Pathol Lab Med* 2023 Feb 01;147(2):227-235 [FREE Full text] [doi: [10.5858/arpa.2021-0115-EP](https://doi.org/10.5858/arpa.2021-0115-EP)] [Medline: [35687790](https://pubmed.ncbi.nlm.nih.gov/35687790/)]
27. Souchet AD, Lourdeaux D, Burkhardt J, Hancock PA. Design guidelines for limiting and eliminating virtual reality-induced symptoms and effects at work: a comprehensive, factor-oriented review. *Front Psychol* 2023 Jun 9;14:1161932 [FREE Full text] [doi: [10.3389/fpsyg.2023.1161932](https://doi.org/10.3389/fpsyg.2023.1161932)] [Medline: [37359863](https://pubmed.ncbi.nlm.nih.gov/37359863/)]
28. Weech S, Kenny S, Barnett-Cowan M. Presence and Cybersickness in Virtual Reality Are Negatively Related: A Review. *Front Psychol* 2019;10:158 [FREE Full text] [doi: [10.3389/fpsyg.2019.00158](https://doi.org/10.3389/fpsyg.2019.00158)] [Medline: [30778320](https://pubmed.ncbi.nlm.nih.gov/30778320/)]
29. Yao R, Heath T, Davies A, Forsyth T, Mitchell N, Hoberman P. *Oculus VR best practices guide*. Oculus VR. 2014. URL: <http://brianschrank.com/vrgames/resources/OculusBestPractices.pdf> [accessed 2024-04-17]
30. Gavvani A, Nesbitt K, Blackmore K, Nalivaiko E. Profiling subjective symptoms and autonomic changes associated with cybersickness. *Auton Neurosci* 2017 Mar;203:41-50. [doi: [10.1016/j.autneu.2016.12.004](https://doi.org/10.1016/j.autneu.2016.12.004)] [Medline: [28010995](https://pubmed.ncbi.nlm.nih.gov/28010995/)]
31. Maslach C, Schaufeli W, Leiter M. Job burnout. *Annu Rev Psychol* 2001;52:397-422. [doi: [10.1146/annurev.psych.52.1.397](https://doi.org/10.1146/annurev.psych.52.1.397)] [Medline: [11148311](https://pubmed.ncbi.nlm.nih.gov/11148311/)]

32. Edú-Valsania S, Laguía A, Moriano JA. Burnout: a review of theory and measurement. *Int J Environ Res Public Health* 2022 Feb 04;19(3):1780 [FREE Full text] [doi: [10.3390/ijerph19031780](https://doi.org/10.3390/ijerph19031780)] [Medline: [35162802](https://pubmed.ncbi.nlm.nih.gov/35162802/)]
33. Forné C, Yuguero O. Factor structure of the Maslach Burnout Inventory Human Services Survey in Spanish urgency healthcare personnel: a cross-sectional study. *BMC Med Educ* 2022 Aug 12;22(1):615 [FREE Full text] [doi: [10.1186/s12909-022-03666-3](https://doi.org/10.1186/s12909-022-03666-3)] [Medline: [35962362](https://pubmed.ncbi.nlm.nih.gov/35962362/)]
34. Cañadas-de la Fuente GA, San Luis C, Lozano LM, Vargas C, García I, de la Fuente EI. Evidencia de validez factorial del Maslach Burnout Inventory y estudio de los niveles de burnout en profesionales sanitarios. *Revista Latinoamericana de Psicología* 2014;46(1):44-52 [FREE Full text]
35. Hernández Vargas CI, Llorens Gumbau S, Rodríguez Sánchez AM. Burnout en personal sanitario: validación de la escala MBI en México. *Forum de recerca*. URL: <http://www.want.uji.es/download/burnout-en-personal-sanitario-validacion-de-la-escala-mbi-en-mexico/> [accessed 2024-04-17]
36. Maslach C, Jackson SE, Leiter MP. Maslach Burnout Inventory. In: Zalaquett CP, Wood RJ, editors. *Evaluating stress: A book of resources*. Lanham, MD: Scarecrow Education; 1997:191-218.
37. Utrecht Work Engagement Scale. Occupational Health Psychology Unit, Utrecht University. URL: https://www.wilmarschaufeli.nl/publications/Schaufeli/Test%20Manuals/Test_manual_UWES_Espanol.pdf [accessed 2024-04-17]
38. Torabinia M, Mahmoudi S, Dolatshahi M, Abyaz MR. Measuring engagement in nurses: the psychometric properties of the Persian version of Utrecht Work Engagement Scale. *Med J Islam Repub Iran* 2017 Jan 01;31(1):15-89 [FREE Full text] [doi: [10.18869/mjiri.31.15](https://doi.org/10.18869/mjiri.31.15)] [Medline: [28955665](https://pubmed.ncbi.nlm.nih.gov/28955665/)]
39. Domínguez-Salas S, Rodríguez-Domínguez C, Arcos-Romero A, Allande-Cussó R, García-Iglesias J, Gómez-Salgado J. Psychometric Properties of the Utrecht Work Engagement Scale (UWES-9) in a Sample of Active Health Care Professionals in Spain. *Psychol Res Behav Manag* 2022;15:3461-3472 [FREE Full text] [doi: [10.2147/PRBM.S387242](https://doi.org/10.2147/PRBM.S387242)] [Medline: [36474956](https://pubmed.ncbi.nlm.nih.gov/36474956/)]
40. Ruiz-Frutos C, Ortega-Moreno M, Soriano-Tarín G, Romero-Martín M, Allande-Cussó R, Cabanillas-Moruno JL, et al. Psychological Distress Among Occupational Health Professionals During Coronavirus Disease 2019 Pandemic in Spain: Description and Effect of Work Engagement and Work Environment. *Front Psychol* 2021 Dec 16;12:765169 [FREE Full text] [doi: [10.3389/fpsyg.2021.765169](https://doi.org/10.3389/fpsyg.2021.765169)] [Medline: [34975655](https://pubmed.ncbi.nlm.nih.gov/34975655/)]
41. Han S. Nurses' job crafting, work engagement, and well-being: a path analysis. *BMC Nurs* 2023 Oct 30;22(1):405 [FREE Full text] [doi: [10.1186/s12912-023-01573-6](https://doi.org/10.1186/s12912-023-01573-6)] [Medline: [37904210](https://pubmed.ncbi.nlm.nih.gov/37904210/)]
42. Lee M, Cha C. Interventions to reduce burnout among clinical nurses: systematic review and meta-analysis. *Sci Rep* 2023 Jul 06;13(1):10971. [doi: [10.1038/s41598-023-38169-8](https://doi.org/10.1038/s41598-023-38169-8)] [Medline: [37414811](https://pubmed.ncbi.nlm.nih.gov/37414811/)]
43. Slater M, Sanchez-Vives M. Enhancing our lives with immersive virtual reality. *Front Robot AI* 2016 Dec 19;3:74. [doi: [10.3389/frobt.2016.00074](https://doi.org/10.3389/frobt.2016.00074)]

Abbreviations

MBI: Maslach Burnout Inventory

UWES: Utrecht Work Engagement Scale

VR: virtual reality

Edited by G Eysenbach, T Leung; submitted 20.12.23; peer-reviewed by D Silber, O Aly; comments to author 09.04.24; revised version received 15.04.24; accepted 15.04.24; published 25.04.24.

Please cite as:

Ferrer Costa J, Moran N, Garcia Marti C, Colmenares Hernandez LJ, Radu Ciorba Ciorba F, Ciudad MJ

Immediate Impact of an 8-Week Virtual Reality Educational Program on Burnout and Work Engagement Among Health Care Professionals: Pre-Post Pilot Study

JMIR XR Spatial Comput 2024;1:e55678

URL: <https://xr.jmir.org/2024/1/e55678>

doi: [10.2196/55678](https://doi.org/10.2196/55678)

PMID:

©Jose Ferrer Costa, Nuria Moran, Carlos Garcia Marti, Leomar Javier Colmenares Hernandez, Florin Radu Ciorba Ciorba, Maria Jose Ciudad. Originally published in *JMIR XR and Spatial Computing* (<https://xr.jmir.org/>), 25.04.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in *JMIR XR and Spatial Computing*, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Original Paper

Perspectives of Medical Students and Developers Regarding Virtual Reality, Augmented Reality, Mixed Reality, and 3D Printing Technologies: Survey Study

Young Hyun Yun¹, PhD; Dong Hoon Shin¹, MD, MS, MA, PhD; Hyung Jin Choi^{1,2}, MD, PhD

¹Department of Anatomy and Cell Biology, Seoul National University College of Medicine, Seoul, Republic of Korea

²Department of Biomedical Sciences, Seoul National University College of Medicine, Seoul, Republic of Korea

Corresponding Author:

Hyung Jin Choi, MD, PhD

Department of Anatomy and Cell Biology

Seoul National University College of Medicine

103 Daehak-ro

Jongno-gu

Seoul, 03080

Republic of Korea

Phone: 82 27408204

Email: hjchoi@snu.ac.kr

Abstract

Background: Emerging technologies, such as virtual reality (VR), augmented reality (AR), mixed reality (MR), and 3D printing (3DP), have transformative potential in education and health care. However, complete integration has not yet been achieved, and routine use is limited. There may exist gaps in the perspectives of these technologies between users and developers, and improvement may be necessary in developing such technologies.

Objective: The purpose of this study was to investigate the gaps in perspectives between medical students and developers in medical education regarding satisfaction and anticipated future use of VR, AR, MR, and 3DP technologies, as well as developers' perspectives on their advantages and current challenges.

Methods: This retrospective survey study was conducted during a 4-hour elective course over a period of 4 weeks. In this course, computed tomography scans of congenital heart disease patients, medical image processing software, head-mounted displays, and a virtual table were used. Student pre- and postsurveys and the developer survey included demographic and other characteristics, satisfaction, and anticipated future use of VR, AR, MR, and 3DP technologies. The advantages and current challenges of these technologies were only assessed in the developer survey.

Results: The study enrolled 41 participants, including 15 first-year medical students and 26 software and content developers. Students were more satisfied than developers across AR, VR, and 3DP in terms of overall satisfaction (VR and AR: $P < .001$; 3DP: $P = .002$), esthetics (VR: all $P < .001$; AR: vividness, $P = .006$ and design, $P < .001$; 3DP: vividness, $P = .001$ and design, $P = .002$), and continuous use intention (VR: repetition, $P = .04$ and continuous use, $P = .02$). Particularly in VR, satisfaction with reality was higher among students than among developers (real world, $P = .006$). Developers anticipated future use of MR for educating medical students and residents, individual and collaborative surgical planning, and performing surgery on patients. In contrast, students anticipated future use of VR primarily for student education, 3DP for resident education and individual surgical planning, and AR for collaborative surgical planning and performing surgery on patients. Developers perceived the inherent capabilities of VR, AR, and MR technologies as strengths, with hardware performance identified as a drawback. For 3DP, the possibility of customized product manufacturing was seen as an advantage, while cost was seen as a disadvantage.

Conclusions: This study elucidated the different perspectives between medical students and developers regarding 3D technologies, highlighting the discrepancy in potential applications and challenges within the medical field. These findings will guide the integration of 3D technologies in education and health care to fulfill the needs and goals of both medical students and developers.

(*JMIR XR Spatial Comput* 2024;1:e54230) doi:[10.2196/54230](https://doi.org/10.2196/54230)

KEYWORDS

medical student; developer; virtual reality; augmented reality; mixed reality; 3D printing; perspective; survey

Introduction

Background

In recent years, 3D technologies, including virtual reality (VR), augmented reality (AR), mixed reality (MR), and 3D printing (3DP), have shown considerable potential to revolutionize the fields of education and health care [1-3]. Each of these technologies offers different capabilities. The basic principle of VR involves the immersion of users in artificial environments, providing complete immersion and removing them from their immediate surroundings [4]. On the other hand, the principle of AR involves overlaying digital information onto the real world, allowing interaction between the physical and digital realms [5]. MR goes a step further by merging tangible and virtual worlds [6]. Unlike VR, which fully immerses the user in a virtual environment, and AR, which overlays digital information onto the physical world, MR is defined as a technology that seamlessly merges the physical world with the virtual world, allowing physical and digital objects to coexist and interact in real time [7]. In MR, virtual objects appear to exist in the same space as physical objects, and users can interact with both in a natural and intuitive way. These technologies are commonly experienced using headsets, allowing hands-free viewing of digital information within the user's view. Additionally, 3DP is a method of creating a 3D object layer by layer from a computer-generated design [5]. Beyond these basic principles, these technologies have become powerful tools in facilitating practical training and skill development. Numerous studies have highlighted the importance of integrating these cutting-edge technologies into medical and surgical education [8-10].

VR is versatile with applications in 3D anatomical models, surgical planning, and medical skills practice simulators [11]. It has been actively evaluated for its efficacy in anatomy education and has been often compared with traditional methods like dissection and lectures, as well as modern techniques like 2D images and blended instructions [12,13]. In surgical education, VR can effectively address challenges, such as the shortage of available mentors, optimization of training time, and mitigation of the complexities associated with operative procedures [14]. Additionally, by replicating complex surgical scenarios in a controlled and risk-free environment, VR offers a safe space for trainees to enhance their skills and decision-making processes.

AR has been incorporated into different phases of medical training, and it serves as an essential tool for anatomical instruction, which can assist students during classroom studies, a tool in image-based training simulators, and an interactive platform to improve clinical skills [15]. The integration of AR has revolutionized medical education by providing students with real-time visualizations of complex anatomical structures and creating interactive and immersive learning experiences that deepen their understanding of medical concepts [16]. In addition, AR-based training simulators enable learners to

improve their practical skills and confidence by allowing them to practice medical procedures in a simulated digital environment before performing them in clinical settings [17]. There is a key difference between AR-based training simulators and VR-based training simulators. VR-based training simulators simulate the actual workspace within a 3D modeling environment and involve the handling of virtual objects using controllers. However, AR-based training simulators allow users to interact with digital elements while still being aware of their physical surroundings [18]. This allows for a more seamless integration of virtual elements with real-world objects and scenarios, offering unique training opportunities that VR alone may not be able to provide.

MR has rapidly advanced in recent years, establishing itself as a fundamental research direction within the field of intelligent medicine. There are significant numbers of MR applications in surgical training and planning [19,20]. Previous studies have found that by expanding upon conventional computer-assisted surgical techniques, MR offers significant potential for enhancing orthopedic training and needle insertion skills [3,21]. This transformative impact extends beyond the confines of surgical applications, encompassing the sphere of medical education as a whole. Some pioneering research has demonstrated that MR has the potential to enhance the efficacy of conveying intricate content through remote learning, a modality that remains pivotal in the field of education [22].

3DP provides a tangible and immersive approach to medical and surgical education [23]. 3DP enables the production of objects with very intricate details and offers the versatility to print a model with different materials, including hydrogels, thermoplastics and thermosets, metals, and ceramics [2,24]. In addition, personalized patient-specific 3DP models help students understand variation and pathology, while surgical planning benefits from accurate organ replicas that enhance visualization and reduce errors [25]. Trainees train their hands-on skills on 3D-printed models in a risk-free environment, and educators simulate complex cases for better decision-making [26]. Furthermore, 3DP plays a crucial role in advancing medical research by facilitating the prototyping of medical innovations, including devices and implants, thus shaping the future of the field [27,28].

These technologies have been well developed in recent years, and this is reflected in a variety of medical specialties in medical education and health care. While these technologies have been widely used to complement existing methods, they are increasingly becoming integral tools, particularly in settings where conventional approaches face limitations or challenges. In educational settings that have constraints, such as limited access to cadavers, high costs, concerns about formaldehyde exposure, ethical considerations, and challenges posed by pandemics, these technologies have gradually replaced traditional methods for medical students [29,30]. Similarly, in health care, personalized instruments, along with advancements like bone grafting and customized implants, are replacing

traditional approaches [31]. As they continue to complement and replace traditional methods, they offer innovative solutions to address various challenges and constraints encountered in both education and health care.

In South Korea, after students are accepted into medical school, they typically spend 2 years in premedical education. During this premedical education, they study basic subjects, such as basic sciences, and other fundamental subjects essential for their medical studies. Therefore, the first year of medical school is an appropriate time to introduce these latest technologies. Because students have already established a solid foundation in basic sciences during their premedical education, they are better equipped to grasp the complexities of these technologies and integrate them into their medical education effectively. The current technology curriculum is situated in the context following the completion of the anatomy course and preceding the commencement of the clinical curriculum. Prior to enrolling in this technology curriculum at Seoul National University College of Medicine, students are exposed to heart content in their human anatomy course using these tools. A survey comparing student evaluation of the same content through traditional education versus the use of these tools revealed that the tools were considerably helpful [32].

Theoretical Background

While numerous studies have examined the satisfaction and effectiveness among medical students, residents, and fellows [33-36], complete integration into routine education and health care has not been achieved. These studies have primarily focused on users, with little attention given to the perspectives of developers, who are responsible for creating these technologies. Consequently, the findings offer an incomplete picture. As these technologies continue to evolve in medical education, it becomes essential to understand the perspectives of both medical students and developers regarding the technologies.

Relationship Between Users and Developers

Users and developers are commonly considered 2 distinct groups of people [37]. Due to differences in backgrounds and situations, developers and users often share different and sometimes conflicting interests during the software development process. The root cause of many issues is perceived to be ongoing cultural differences. Other theories suggest that personality differences or even differences in how users and developers think cause these barriers [38]. Developers tend to be achievement-oriented and are intrinsically motivated to develop excellent software, while users are primarily focused on improving efficiency and solving problems [39]. The potential conflict of interest between them can negatively affect the performance of software development. Therefore, a study is needed to understand the gaps in their perspectives regarding the range of tools and techniques, which might support future development. Understanding their perspectives might help in refining the implementation strategies of these technologies in the large scope of curriculum development.

User and Developer Satisfaction and System Success

User satisfaction is one of the most frequently cited factors for measuring system success and one of the most difficult factors to measure [40]. A great deal of research has been conducted to understand the notion of user satisfaction. User satisfaction, as defined by previous researchers, encompasses meeting user needs [41], positive cognitive responses to system use [42], and measurable effects in projects [43]. In education, satisfaction plays a crucial role as a barrier to continuous use and adoption of these technologies [44]. While people may use various technologies without being fully satisfied with them, in the context of education, satisfaction impacts the effectiveness of learning experiences [45]. Students who are dissatisfied with the technologies used in their education may experience hindered engagement, motivation, and, ultimately, compromised learning outcomes [46]. High satisfaction with technology not only correlates with actual experiences of the technology but also enables individuals to anticipate which technologies may be beneficial in future situations. In addition, considering that developers not only represent the core of the development process but also account for the largest cost in software development, it is necessary to investigate developer satisfaction. Ultimately, developer satisfaction is essential for system development success.

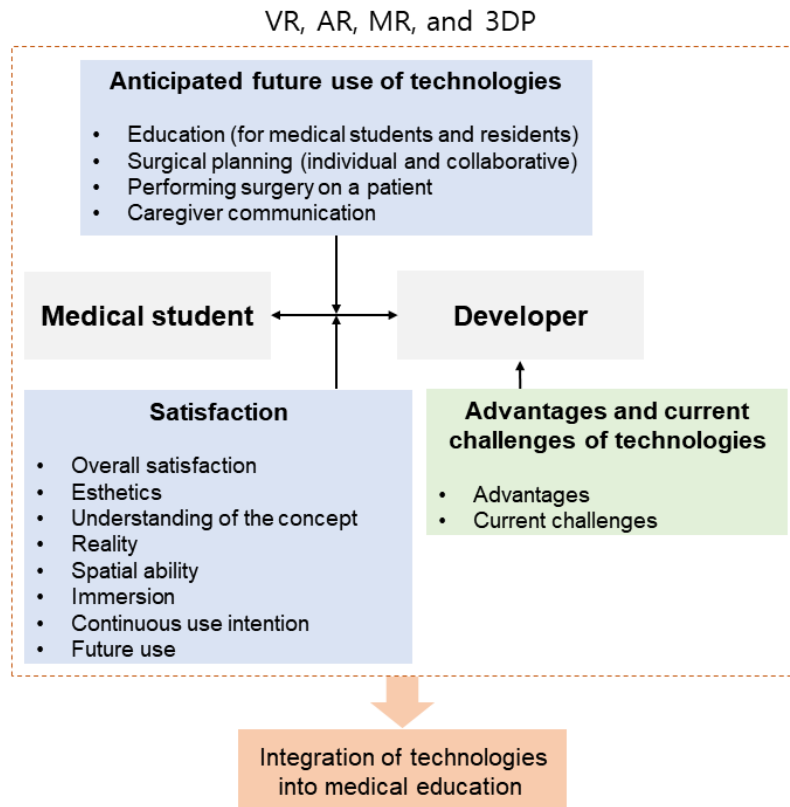
User and Developer Anticipations Regarding Technology

Anticipations of future use in technological development are more than simply descriptions of future products and systems. These anticipations can change the application process of novel technology in medical education as they guide the actions of technology developers [47]. At the same time, extrapolating future technology from past developments can narrow down the potential paths of technological advancement [48]. However, users play a role in shaping the future of technology, as the shape of technology depends on their anticipations of use [47]. To conclude, it is important to consider anticipations for investigating the gap in medical education. We suggest viewing envisaged sociotechnical futures as negotiation arenas between the present and the imagined futures. There is a lack of knowledge on differences in user and developer anticipations regarding the types of technologies that are likely to be widely used in different scenarios. In medical education, there may remain a gap in the anticipated use of these technologies between medical students and developers, and it may be needed to figure out the differences in anticipations to effectively bridge this gap.

Conceptual Framework

This study hypothesized a conceptual framework (Figure 1) in which there is a gap between medical students and developers in terms of satisfaction and anticipated future use of VR, AR, MR, and 3DP technologies, and this gap is associated with the complete integration into medical education. Additionally, from a technological perspective, this study hypothesized that factors related to the advantages and current challenges associated with these technologies from the developers' perspectives could potentially delay the integration of medical education.

Figure 1. Conceptual framework of this study. 3DP: 3D printing; AR: augmented reality; MR: mixed reality; VR: virtual reality.



Study Questions

The aim of this study was to investigate the gap in perspectives between medical students and developers regarding the satisfaction and anticipated future use of VR, AR, MR, and 3DP technologies, as well as developers' perspectives on their advantages and current challenges. The following specific research questions guided this study:

1. What is the difference in satisfaction levels with VR, AR, MR, and 3DP between medical students and developers?
2. What differences exist in the anticipated future use of VR, AR, MR, and 3DP between medical students and developers?
3. What are the developers' perceptions of the advantages and current challenges associated with VR, AR, MR, and 3DP?

Methods

Participants

All participants voluntarily enrolled in an elective course on 3D imaging software and the applications of 3D technology for human anatomy at Seoul National University College of Medicine, Seoul, Republic of Korea, and were voluntarily recruited. In the academic year 2023, 15 first-year medical students and 26 software and content developers with expertise in VR, AR, or 3DP participated in this study.

Curriculum and Study Design

The course and the surveys were designed for educational quality improvement purposes prospectively before actual application of the curriculum. The statistical research was

performed retrospectively after the completion of the curriculum.

Contents and Schedule for the Elective Course

The elective course spanned 4 weeks with 4 sessions, each lasting 4 hours (Table 1). A graphical diagram of the elective course and a workflow diagram detailing the hands-on practice are shown in Figures 2 and 3. During the initial 3 weeks, the curriculum included lectures and hands-on sessions focusing on the application of artificial intelligence (AI) technology in medical imaging. The AI-based image processing software quickly and automatically segmented the anatomical structures, allowing for adequate processing within the first 3 weeks. Only the finer anatomical structures required separate segmentation. The students were divided into 4 groups and used medical image processing software to outline anatomical structures. In this study, heart models were selected owing to complex 3D relationships between components within the thoracic cavity. These heart models were personalized and customized to match the anatomical structure of each patient with congenital heart disease (CHD). The process of creating a 3D reconstruction from a patient's computed tomography scan is shown in Multimedia Appendix 1. The 3D segmented models were constructed for an interrupted aortic arch (Multimedia Appendix 2), Ebstein anomaly (Multimedia Appendix 3), transposition of the great arteries (Multimedia Appendix 4), and major aortopulmonary collateral arteries (Multimedia Appendix 5). The segmented and processed images were then integrated into various tools: VR via Oculus Quest 2 (Meta), AR via HoloLens 2 (Microsoft Corp), and 3DP for physical modeling. In the final week, students presented on the future of medical education and clinical environments, drawing upon tools from the first 3

weeks of the course. In the curriculum management process, faculty members specializing in anatomy education oversaw the development of these tools and modalities. In addition, the course in which these tools were introduced was typically taught

by not only anatomy experts, who use these technologies effectively in anatomy education, but also software developers. Content developers in the course worked with students to create CHD content.

Table 1. Table of contents and schedule for the elective course at Seoul National University College of Medicine, 2023.

Week and time	Topic	Detailed content	Teaching method
Week 1: Medical image-based AI^a technology (n=5)			
1:00-1:10 PM	Presurvey for students	• N/A ^b	Survey
1:10-2:00 PM	Understanding medical image-based AI technology	• N/A	Lecture
2:00-2:10 PM	Rest	• N/A	N/A
2:10-2:30 PM	Use of AI technology in medical imaging; 3DP ^c	• N/A	Lecture
2:30-2:40 PM	Rest	• N/A	N/A
2:40-3:00 PM	Use of AI technology in medical imaging; VR ^d , AR ^e , and MR ^f	• N/A	Lecture
3:00-3:10 PM	Rest	• N/A	N/A
3:10-4:50 PM	Learning the functions of medical image processing software	• N/A	Lecture and hands-on practice
4:50-5:00 PM	Course wrap-up	• N/A	N/A
Week 2: AI segmentation using medical image processing software (n=15; 4 groups)			
1:00-1:50 PM	AI segmentation using medical image processing software	• AI segmentation on cases of CHD ^g patients, including IAA ^h , Ebstein anomaly, TGA ⁱ , and MAPCA ^j	Hands-on practice
1:50-2:00 PM	Rest	• N/A	N/A
2:00-2:50 PM	AI segmentation using medical image processing software	• AI segmentation on the abovementioned cases	Hands-on practice
2:50-3:00 PM	Rest	• N/A	N/A
3:00-3:50 PM	AI segmentation using medical image processing software	• AI segmentation on the abovementioned cases	Hands-on practice
3:50-4:00 PM	Rest	• N/A	N/A
4:00-4:50 PM	AI segmentation using medical image processing software	• AI segmentation on the abovementioned cases	Hands-on practice
4:50-5:00 PM	Course wrap-up	• N/A	N/A
Week 3: VR, AR, and 3DP experience (n=15; 4 groups)			
1:00-4:30 PM	VR experience	<ul style="list-style-type: none"> • Anatomy structures • Pediatric CHD model, including IAA, Ebstein anomaly, TGA, and MAPCA (patient-specific model) • Digestive process • Respiratory process • Muscle movement 	Group rotation experience
1:00-4:30 PM	AR experience	<ul style="list-style-type: none"> • Pediatric CHD model, including IAA, Ebstein anomaly, TGA, and MAPCA (patient-specific model) • Kidney cancer model • Brain tumor model 	Group rotation experience

Week and time	Topic	Detailed content	Teaching method
1:00-4:30 PM	3DP experience	<ul style="list-style-type: none"> Pediatric CHD model, including IAA, Ebstein anomaly, TGA, and MAPCA (patient-specific model) Simulator model for surgery training 	Group rotation experience
1:00-4:30 PM	3DP lab tour	<ul style="list-style-type: none"> 3DP lab Production process lab 	Group rotation experience
4:30-4:50 PM	Rest	<ul style="list-style-type: none"> N/A 	N/A
4:50-5:00 PM	Course wrap-up	<ul style="list-style-type: none"> N/A 	N/A
Week 4: Presentation (n=15; 4 groups)			
1:00-1:30 PM	Group 1: Presentation and discussion	<ul style="list-style-type: none"> N/A 	Presentation and discussion
1:30-1:40 PM	Rest	<ul style="list-style-type: none"> N/A 	N/A
1:40-2:10 PM	Group 2: Presentation and discussion	<ul style="list-style-type: none"> N/A 	Presentation and discussion
2:10-2:20 PM	Rest	<ul style="list-style-type: none"> N/A 	N/A
2:20-2:50 PM	Group 3: Presentation and discussion	<ul style="list-style-type: none"> N/A 	Presentation and discussion
2:50-3:00 PM	Rest	<ul style="list-style-type: none"> N/A 	N/A
3:00-3:30 PM	Group 4: Presentation and discussion	<ul style="list-style-type: none"> N/A 	Presentation and discussion
3:30-4:00 PM	Rest	<ul style="list-style-type: none"> N/A 	N/A
4:00-4:20 PM	Postsurvey for students and developers	<ul style="list-style-type: none"> N/A 	Survey
4:20-4:40 PM	Group photo	<ul style="list-style-type: none"> N/A 	N/A
4:40-5:00 PM	Course wrap-up	<ul style="list-style-type: none"> N/A 	N/A

^aAI: artificial intelligence.

^bN/A: not applicable.

^c3DP: 3D printing.

^dVR: virtual reality.

^eAR: augmented reality.

^fMR: mixed reality.

^gCHD: congenital heart disease.

^hIAA: interrupted aortic arch.

ⁱTGA: transposition of the great arteries.

^jMAPCA: major aortopulmonary collateral arteries.

Figure 2. Graphical diagram of the elective course. 3DP: 3D printing; AR: augmented reality; MR: mixed reality; VR: virtual reality.

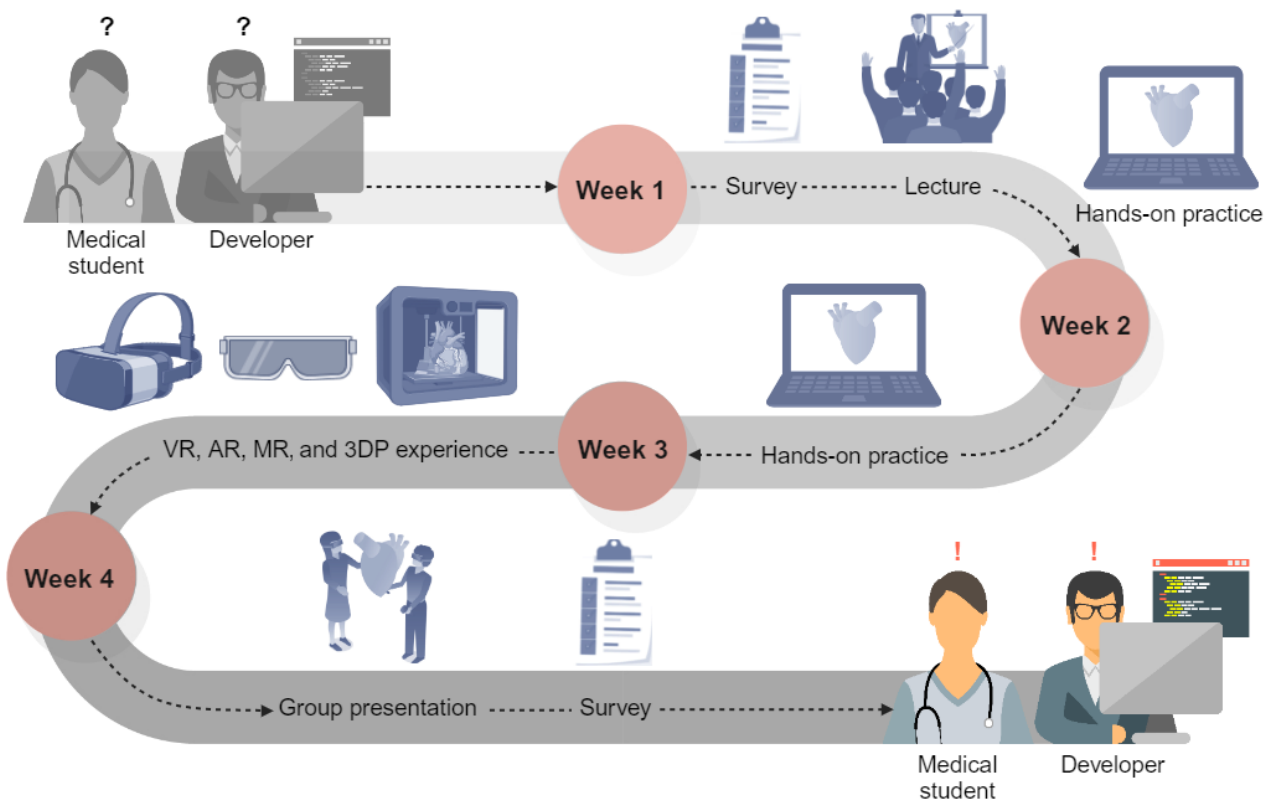
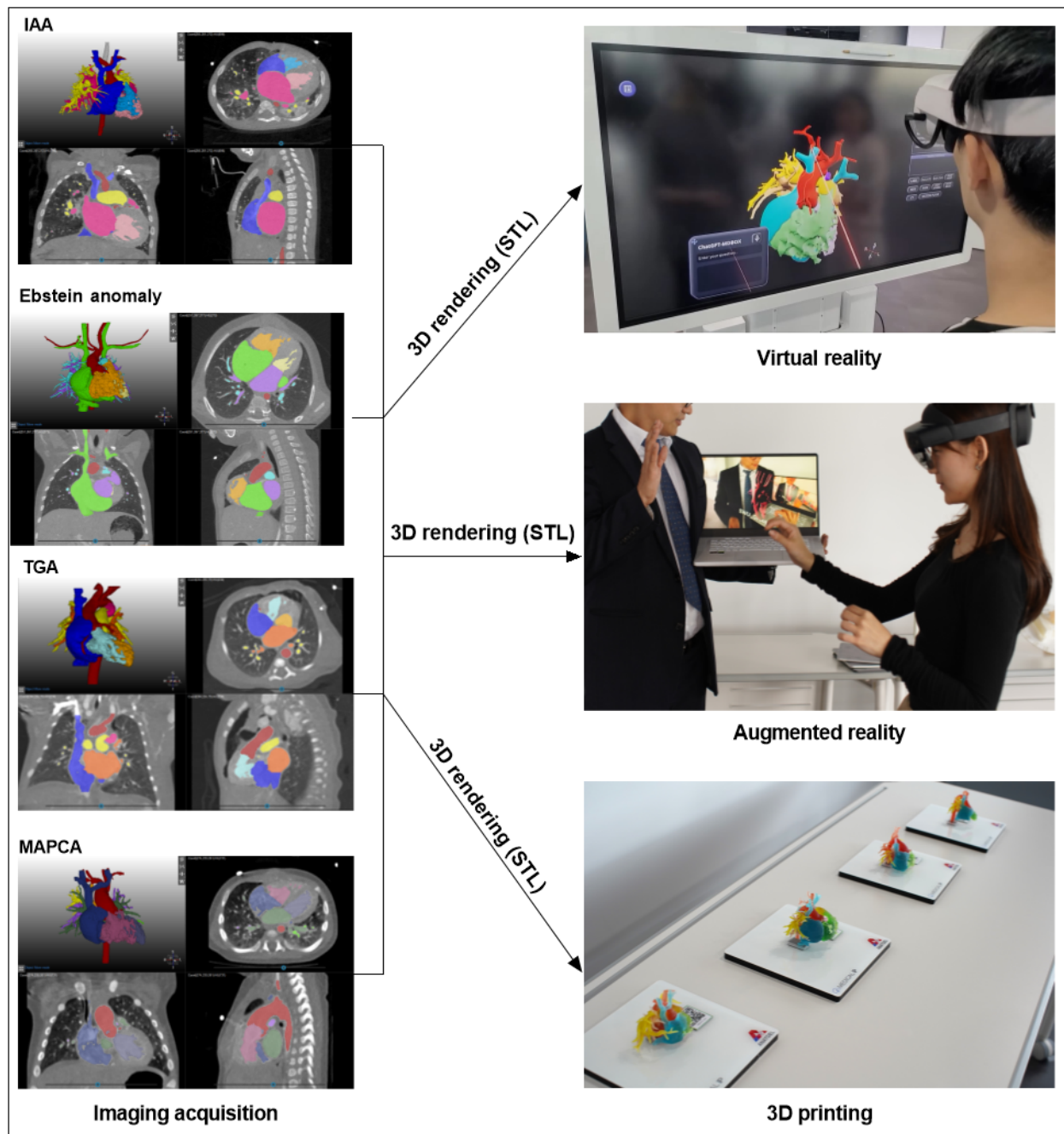


Figure 3. Workflow diagram of hands-on practice for the elective course. Segmented and refined 3D congenital heart disease models are used for not only virtual and augmented reality but also 3D printing. IAA: interrupted aortic arch; MAPCA: major aortopulmonary collateral arteries; STL: standard tessellation language; TGA: transposition of the great arteries.



Devices and Software

This study employed a virtual dissection table (MDBOX, MEDICAL IP Co, Ltd), a VR headset (Oculus Quest 2), an AR headset (HoloLens 2), and medical image processing software (MEDIP PRO, MEDICAL IP Co, Ltd).

Student Pre- and Postsurveys

The students' survey consisted of pre- and postsurveys. The presurvey included questions about demographic information and prior experience with 3D medical technologies. The majority of previous studies used 5-point Likert scale-based questionnaires to assess user satisfaction, device usability,

perceived engagement, and the influence on anatomy education [49]. Therefore, in the postsurvey, students used a 5-point Likert-type scale to indicate their overall satisfaction and satisfaction levels with VR, AR, and 3DP across 7 categories, which were organized into 2 subscales each ([Multimedia Appendix 6](#)). The 7 categories included esthetics, understanding of the concept, reality, spatial ability, immersion, continuous use intention, and future use. The use of new technologies in education is considered to be about experiences that include esthetic enjoyment as well [50]. Moreover, well-designed and esthetically pleasing content is more likely to engage users and improve their overall experience [51]. Clarity and comprehensibility of the content are crucial for users to

effectively grasp concepts. 3D models provide users with the flexibility to explore structures from desired angles, thereby facilitating deeper comprehension and learning [52]. In education, aspects of spatial ability can be enhanced through experience, suggesting the potential for facilitating users' learning of 3D structures [53]. Previous studies have found a correlation between spatial abilities and assessment of anatomy knowledge, with spatial training being shown to improve spatial abilities [54]. In these technology-rich educational environments, immersion has been identified as one of the primary drivers of student learning [55]. Continuous use intention is an important factor for the successful adoption of technology [56]. Additionally, satisfaction with technologies expected to be used in clinical areas or their potential for substitution was also investigated. To further explore students' thoughts and insights through their presentations, students were asked questions about their expectations regarding the use of these technologies in various situational scenarios in the future. These questionnaires were prepared using Google Forms (Google LLC).

Developer Survey

The developers took a single survey, which included demographic information, department affiliation, and years of professional experience. Similar to the student postsurvey, developers rated their overall satisfaction and satisfaction levels with VR, AR, and 3DP using a 5-point Likert-type scale across the same 7 categories organized into 2 subscales each. The survey also inquired about their expectations regarding the integration of these technologies into various medical settings within 5 years. Furthermore, the survey included questions exploring only developers' perspectives on the advantages and challenges of VR, AR, MR, and 3DP. These questionnaires were prepared using Google Forms (Google LLC).

Statistical Analysis

Statistical analyses were performed using SPSS software, version 26 (IBM Corp) and Prism, version 9 (GraphPad). Differences in satisfaction levels between students and developers for VR, AR, and 3DP were assessed using independent *t* tests. Statistical significance was determined at $P < .05$. Owing to the possibility of a type I (false positive) error resulting from the multiple comparison analyses, we applied Bonferroni correction. After Bonferroni correction, most

of the associations were not considered significant, with the adjusted significance level set at $P < .003$.

Ethical Considerations

This study was approved by the Institutional Review Board of Seoul National University College of Medicine (E-2307-030-1447). The study was entirely retrospective (using existing student and developer surveys), and the requirement for informed consent was waived.

Results

Participants

In this survey study, we recruited 15 first-year medical students and 26 software and content developers who participated in a 4-week elective course that combined lectures and hands-on sessions. The data collection started on May 22, 2023, and ended on June 19, 2023.

Demographic and Other Characteristics of Medical Students

The demographic and other characteristics of the 15 medical students are provided in Table 2. Their mean age was 21.5 (SD 1.5) years, and there were 12 (80%) male students and 3 (20%) female students. All students were familiar with VR, and 14 (93%) students were aware of AR and MR. However, 14 (93%) students had difficulty distinguishing between these technologies. Regarding VR content, 11 (73%) students engaged with it 1-3 times a month, with 8 (73%) engaging for educational purposes and 5 (46%) engaging for gaming. AR content was less frequent, with 5 (33%) students experiencing it 1-2 times a year, mainly in gaming (4/5, 80%) and education (2/5, 40%). 3DP content was used 1-2 times a year for educational purposes by 9 (60%) students. Moreover, 11 (73%) students used VR-based medical content, with 6 (55%) students focusing on heart-related content (heart VR education was previously provided in the anatomy curriculum) and 5 (46%) using unknown content. None had prior experience with AR-based medical content, but 2 (13%) students had experience with 3DP-based medical content. Of these 2 students, 1 (50%) used a pediatric cardiac model and 1 (50%) used content of unknown nature.

Table 2. Demographic and other characteristics of medical students (n=15).

Characteristic	Value
Age (years), mean (SD)	21.5 (1.5)
Gender, n (%)	
Male	12 (80)
Female	3 (20)
Please select all the options you have heard of among VR^a, AR^b, MR^c, and 3DP^d, n (%)	
VR	15 (100)
AR	14 (93)
MR	14 (93)
Can you distinguish between VR, AR, and MR? n (%)	
No	14 (93)
Yes	1 (7)
Have you ever experienced VR content? n (%)	
No	4 (27)
Yes	11 (73)
If you have experienced VR content, how often did you experience it?^e, n (%)	
Everyday	0 (0)
3-4 times a week	0 (0)
1-2 times a week	0 (0)
1-3 times a month	11 (100)
1-2 times a year	0 (0)
If you have experienced VR content, please select all the experiences you had^e, n (%)	
Game	5 (46)
Travel	0 (0)
Movies or television shows	0 (0)
Music (eg, concerts and music videos)	0 (0)
Education	8 (73)
Art galleries	0 (0)
Have you ever experienced AR content? n (%)	
No	10 (67)
Yes	5 (33)
If you have experienced AR content, how often did you experience it?^e, n (%)	
Everyday	0 (0)
3-4 times a week	0 (0)
1-2 times a week	0 (0)
1-3 times a month	0 (0)
1-2 times a year	5 (100)
If you have experienced AR content, please select all the experiences you had^e, n (%)	
Game	4 (80)
Travel	0 (0)
Movies or television shows	0 (0)
Music (eg, concerts and music videos)	0 (0)

Characteristic	Value
Education	2 (40)
Art galleries	0 (0)
Have you ever experienced 3DP content? n (%)	
No	6 (40)
Yes	9 (60)
If you have experienced 3DP content, how often did you experience it?^e, n (%)	
Everyday	0 (0)
3-4 times a week	0 (0)
1-2 times a week	0 (0)
1-3 times a month	0 (0)
1-2 times a year	9 (100)
If you have experienced 3DP content, please select all the experiences you had^e, n (%)	
Game	0 (0)
Travel	0 (0)
Movies or television shows	0 (0)
Music (eg, concerts and music videos)	0 (0)
Education	9 (100)
Art galleries	0 (0)
Have you ever experienced VR-based medical content? n (%)	
No	4 (27)
Yes	11 (73)
If you have experienced VR-based medical content, what is the name of the content? (If unknown, please write "unknown")^e, n (%)	
Heart	6 (55)
Unknown	5 (46)
Have you ever experienced AR-based medical content? n (%)	
No	15 (100)
Yes	0 (0)
Have you ever experienced 3DP-based medical content? n (%)	
No	13 (87)
Yes	2 (13)
If you have experienced 3DP-based medical content, what is the name of the content? (If unknown, please write "unknown")^e, n (%)	
Pediatric cardiac model	1 (50)
Unknown	1 (50)

^aVR: virtual reality.

^bAR: augmented reality.

^cMR: mixed reality.

^d3DP: 3D printing.

^eOnly the subgroup of students who experienced either VR, AR, or 3DP.

Demographic and Other Characteristics of Developers

The demographic and other characteristics of the 26 developers are shown in Table 3. Their mean age was 28.2 (SD 4.5) years,

and there were 7 (27%) male developers and 19 (73%) female developers. There was no bias in their expertise. The developers were individuals with backgrounds in software and content development and had various degrees and majors (Multimedia

Appendix 7). Among the 26 developers, 15 (58%) were associated with VR, 4 (15%) with AR, and 10 (39%) with 3DP. Regarding their years of professional experience, most developers had 1 year of experience (9/26, 35%), followed by

less than 1 year of experience (4/26, 15%); 4 and 5 years of experience (each 3/26, 12%); 2, 3, and 8 years of experience (each 2/26, 8%); and 7 years of experience (1/26, 4%).

Table 3. Demographic and other characteristics of developers (n=26).

Characteristic	Value
Age (years), mean (SD)	28.2 (4.5)
Gender, n (%)	
Male	7 (27)
Female	19 (73)
Which departments are you affiliated with? n (%)	
VR ^a	15 (58)
AR ^b	4 (15)
3DP ^c	10 (39)
How many years of experience do you have? n (%)	
No experience	0 (0)
Less than 1 year	4 (15)
1 year	9 (35)
2 years	2 (8)
3 years	2 (8)
4 years	3 (12)
5 years	3 (12)
6 years	0 (0)
7 years	1 (4)
8 years	2 (8)
9 years	0 (0)
More than 10 years	0 (0)

^aVR: virtual reality.

^bAR: augmented reality.

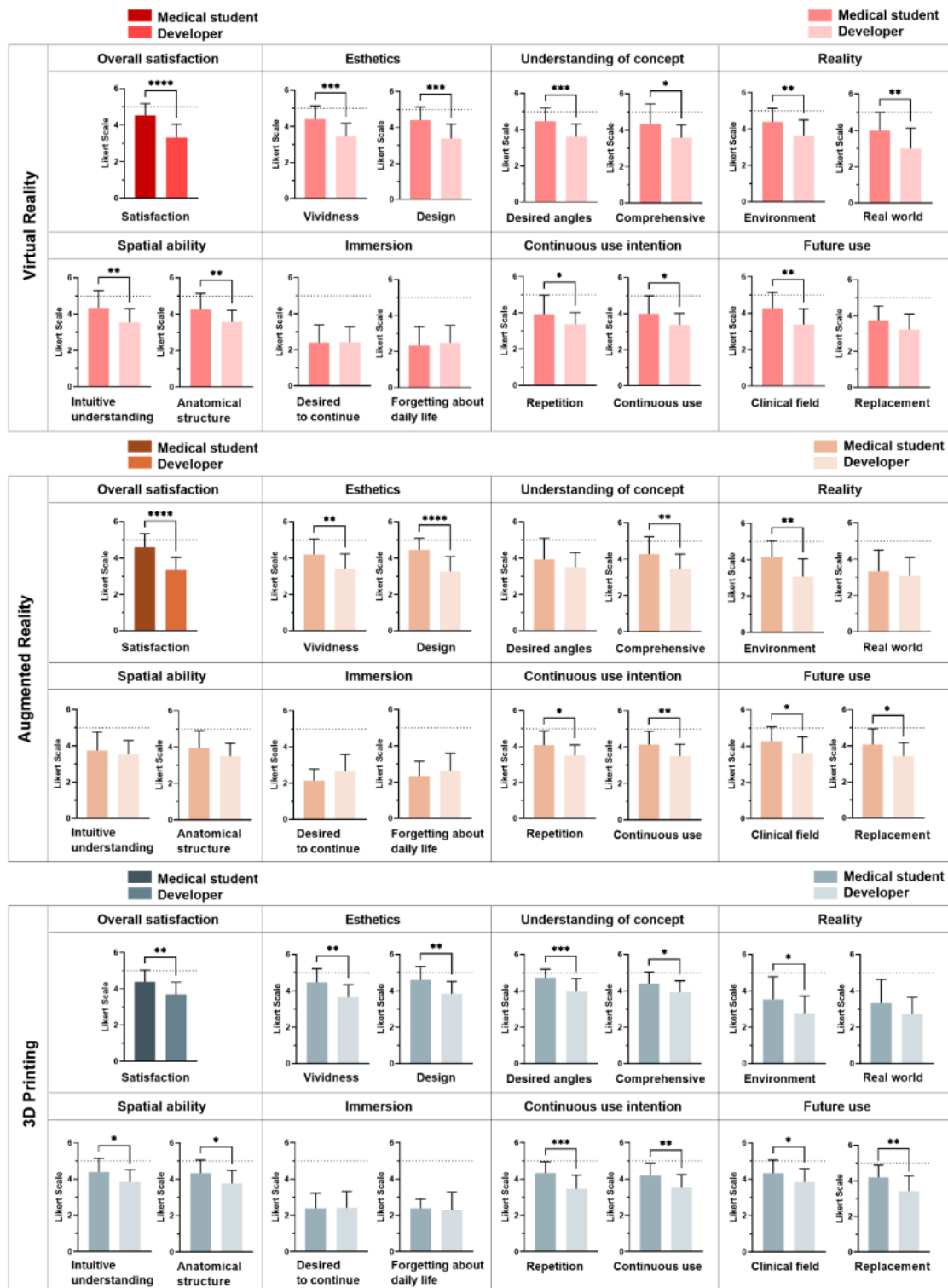
^c3DP: 3D printing.

Levels of Satisfaction With VR, AR, and 3DP Between Medical Students and Developers

Levels of satisfaction with VR, AR, and 3DP among medical students and developers are shown in Figure 4 and Tables S1-S3 in Multimedia Appendix 8. The satisfaction results are presented in terms of overall satisfaction and the following 7 categories: esthetics, understanding of the concept, reality, spatial ability, immersion, continuous intention, and future use. Specifically, 2 questions were included in each category. In terms of esthetics, the vividness and design of the content were considered. For understanding of the concept, questions assessed how easily

participants understood the content and if they were able to learn effectively. Reality focused on whether participants felt a sense of realism within the content and its surroundings. Spatial ability questions evaluated participants' satisfaction to intuitively grasp the structures and understand the relationships between different structures. Continuous use intention investigated participants' desire to repeatedly engage with the content and continue its use. Future use included specific inquiries about the potential application of these technologies in clinical settings and their potential to replace conventional methods.

Figure 4. Medical students' (n=15) and developers' (n=26) levels of satisfaction with virtual reality, augmented reality, and 3D printing have been ranked on a 5-point Likert-type scale (1=very dissatisfied to 5=very satisfied). Participants were asked about their overall satisfaction with virtual reality, augmented reality, and 3D printing, as well as their satisfaction with 7 categories organized into 2 subscales. * $P < .05$, ** $P < .01$, *** $P < .001$, **** $P < .0001$.



Overall satisfaction with VR, AR, and 3DP was significantly higher among students than among developers. There was no significant difference in satisfaction with immersion in VR, AR, and 3DP between medical students and developers. In the case of VR (Figure 4 and Table S1 in Multimedia Appendix 8), the satisfaction levels of students were significantly higher than those of developers in esthetics (vividness: 4.52 vs 3.31; design:

4.40 vs 3.38), understanding of the concept (desired angles: 4.47 vs 3.62; comprehensive: 4.33 vs 3.58), reality (environment: 4.40 vs 3.65; real world: 4.00 vs 3.00), spatial ability (intuitive understanding: 4.33 vs 3.54; spatial perception: 4.27 vs 3.58), continuous use intention (repetition: 3.93 vs 3.39; continuous use: 4.00 vs 3.39), and future use (clinical field: 4.27 vs 3.39). However, after Bonferroni correction to adjust for

multiple variables, only overall satisfaction ($P < .001$), esthetics (vividness and design, $P < .001$), and understanding of the concept (desired angles, $P < .001$) remained statistically significant.

Similarly, in the case of AR (Figure 4 and Table S2 in Multimedia Appendix 8), the satisfaction levels of students were significantly higher than those of developers in esthetics (vividness: 4.20 vs 3.42; design: 4.47 vs 3.27), understanding of the concept (comprehensive: 4.27 vs 3.46), reality (environment: 4.13 vs 3.08; real world: 4.00 vs 3.00), continuous use intention (repetition: 4.07 vs 3.50; continuous use: 4.13 vs 3.50), and future use (clinical field: 4.27 vs 3.61; replacement: 4.07 vs 3.42). However, after Bonferroni correction to adjust for multiple variables, only overall satisfaction ($P < .001$), esthetics (design, $P < .001$), and reality (environment, $P = .002$) remained statistically significant.

In the case of 3DP (Figure 4 and Table S3 in Multimedia Appendix 8), the satisfaction levels of students were significantly higher than those of developers in esthetics (vividness: 4.47 vs 3.65; design: 4.60 vs 3.85), understanding of the concept (desired angles: 4.73 vs 3.96; comprehensive: 4.40 vs 3.92), reality (environment: 3.53 vs 2.77), spatial ability (intuitive understanding: 4.40 vs 3.85; spatial perception: 4.33 vs 3.77), continuous use intention (repetition: 4.33 vs 3.46; continuous use: 4.20 vs 3.54), and future use (clinical field: 4.33 vs 3.85; replacement: 4.20 vs 3.42). However, after Bonferroni correction to adjust for multiple variables, only overall satisfaction ($P < .001$), esthetics (vividness, $P = .001$; design, $P = .002$), understanding of the concept (desired angles, $P < .001$), and continuous use intention (repetition, $P < .001$) remained statistically significant.

Anticipations for the Future Use of VR, AR, MR, and 3DP Between Medical Students and Developers

Future usage expectations of VR, AR, MR, and 3DP between medical students and developers are illustrated in Multimedia Appendix 9. Students expected VR and AR to be the most frequently used technologies in medical education (8/15, 53% and 5/15, 33%, respectively), while MR and 3DP were less anticipated. In contrast, 10 (38%) developers predicted MR to be the most widely used technology, followed by 3DP, with VR and AR having low expected use. In educating residents, 7 (47%) students anticipated 3DP to be the most widely used technology, followed by MR, VR, and AR. Moreover, 11 (42%) developers expected MR to be the dominant technology, followed by 3DP, AR, and VR.

For individual surgical planning, 7 (47%) students expected 3DP to be the most widely used technology, followed by VR, AR, and MR. Moreover, 11 (42%) developers anticipated MR to be the most widely used technology, followed by 3DP, VR, and AR. In collaborative surgical planning, 6 (46%) students anticipated AR to be the most widely used technology, followed by MR, VR, and 3DP. Moreover, 12 (46%) developers expected MR to be the dominant technology, followed by 3DP, AR, and VR.

For surgical procedures on patients, 8 (53%) students expected AR to be the most widely used technology, followed by VR,

MR, and 3DP. Moreover, 14 (52%) developers anticipated MR to be the most widely used technology. In explaining medical information to patients' caregivers, 13 (87%) students anticipated 3DP to be the most widely used technology, followed by VR and MR. Moreover, 10 (38%) developers anticipated 3DP to be the most widely used technology, followed by MR, AR, and VR.

Developers' Perceptions of the Advantages and Current Challenges in VR, AR, MR, and 3DP

The developers' views on the advantages and current challenges of VR, AR, MR, and 3DP are presented in Multimedia Appendix 10. Regarding VR, developers highlighted immersion (11/26, 42%) and the expansiveness of space (8/26, 31%) as key advantages. However, none reported providing experiences similar to real environments as a VR advantage. The main challenge was hardware performance (4/26, 31%), followed by a lack of proactive content production, user-friendliness, and pricing and health issues.

Regarding AR, developers considered engagement in AR (11/26, 42%) as its main advantage, followed by recognizing interactivity and appreciating its ability to provide experiences similar to real environments. None of them reported refining information in AR as an advantage. The main challenge was hardware performance (10/26, 38%), followed by user-friendliness, a lack of proactive content production, and issues related to price and health.

Regarding MR, developers highlighted the integration of real and virtual spaces as the primary advantage (13/26, 50%), with 19% (5/26) noting the provision of realistic virtual spaces. Interactivity and the innovativeness of the experience were also reported. None reported refining information as an advantage. Hardware performance was the primary concern (11/26, 42%), followed by user-friendliness, a lack of proactive content production, and issues related to price and health.

Lastly, regarding 3DP, the primary advantage was the possibility of customized product manufacturing (21/26, 81%). Some developers recognized high accuracy and texture fidelity, and reported increased creative freedom and fast product production. However, none mentioned new design possibilities as an advantage. The primary challenge was manufacturing costs (18/26, 69%), followed by long printing times, difficulty in creating complex models, limitations of materials, and low durability of printed objects (all 2/26, 8%).

Discussion

Overview

Our study aimed to investigate the gaps in perspectives between medical students and developers regarding satisfaction and the most anticipated future use of 3D technologies in medical education. This study offers insights into the differences in satisfaction levels between medical students and developers. This study also provides insights into how anticipations for the use of these technologies differ between medical students and developers across different situational scenarios, as well as how these technologies might be used in specific specialties or areas

of medicine. Additionally, this study sheds light on developers' viewpoints regarding the advantages and challenges associated with these technologies, with the aim of understanding their applicability and limitations in industrial settings.

Principal Findings

The results of this study provide unique evidence that medical students have a higher level of overall satisfaction than developers across VR, AR, and 3DP technologies (Figure 4), which implies that there might be a stronger alignment between the satisfaction and experiences of students with these technologies. It is also noteworthy that medical students were more satisfied than developers with esthetics and the intention to continue use among the 7 categories in VR, AR, and 3DP technologies (Figure 4). We assume that students had positive experiences with the liveliness of technology and design through this course, and based on this experience, they will have high expectations for the future in terms of the vividness and design of these technologies. We believe that students had higher satisfaction with the intention to continue use compared to developers because, as users, they perceive that these technologies yield greater learning effectiveness when used repetitively in the learning environment.

The extent of satisfaction difference between medical students and developers varied across VR, AR, and 3DP. Regarding VR, the difference in satisfaction between medical students and developers was the greatest for esthetics and conceptual understanding (desired angle). This difference could be attributed to the experience students had during the course. Students would have experienced higher satisfaction by interacting with the CHD model they created in the course, such as by rotating the CHD model they created to the desired angle in virtual space, understanding the structure, and applying color. We speculate that esthetics showed the largest extent of difference in AR because students experienced higher satisfaction than developers as the design made it easy for them to recognize and interact with the CHD models they created when presented in a real-world environment. Regarding 3DP, the difference in satisfaction was the greatest for concept understanding (desired angle) and continued use intention (repetition). The patient-customized CHD model could be rotated at any desired angle in real space, and it is assumed that continuous repetition helps students understand complex anatomy.

This study found that when comparing all categories with each technology, medical students were more satisfied than developers in reality (real world) only within VR (Figure 4). Based on the findings of the study, it can be inferred that VR technology, particularly in its current state of hardware development, offers medical students a more realistic and satisfying experience compared to developers. On the other hand, developers may be less satisfied with the current state of technology when considering both the current state of technology and the potential for future technological advances in the industry. This may be because developers who actively participate in the industry are aware of the substantial difficulty needed to increase the realism of VR. In addition, AR showed no significant difference in satisfaction between medical students

and developers in terms of understanding of the concept (desired angles) and spatial ability (Figure 4). Therefore, we conclude that VR might offer a more immersive and satisfying experience for medical students based on current hardware technologies, while AR appears to offer a more balanced perception in terms of conceptual understanding and spatial awareness.

One of the key findings of our study was that there was a gap in anticipations between medical students and developers in 6 situational scenarios regarding the anticipated future use of technology, with the exception of 1 situational scenario (Multimedia Appendix 9). Situational scenarios in which the perspectives differed included educating medical students and residents, individual and collaborative surgical planning, and performing surgery on a patient. In these scenarios, developers perceived MR as a more promising technology. In contrast, medical students perceived VR primarily for student education, 3DP for resident education and individual surgical planning, and AR for collaborative surgical planning and performing surgery on a patient. This discrepancy between the 2 groups is likely from variations in exposure and practical experience with these technologies. Although students experienced VR, AR, and 3DP in their elective course, they were not exposed to MR. Despite the limited exposure to MR among medical students, we can speculate on their perspectives regarding its future use based on their experiences. Medical students may see VR primarily for undergraduate education because of its immersive and interactive nature, allowing for realistic simulations [4]. They may see 3DP as beneficial for resident training and individual surgical planning because of its hands-on nature, allowing them to create physical models that can enhance their understanding of anatomical structures and medical conditions. This perception could be attributed to its potential for customized product manufacturing, which could potentially facilitate clearer communication of medical information to nonexperts. This result is consistent with the results of previous studies, which tended to report positive correlations between the use of 3DP and resident education and explanation to patient caregivers [28,57-59]. Regarding AR, medical students may see it as suitable for collaborative surgical planning and performing surgery on a patient because of its potential to overlay digital information onto the real surgical environment, providing surgeons with real-time guidance and information during procedures. This aligns with existing research on its benefits in specific surgical procedures, such as spine and orthopedic surgeries [60,61]. Our study implied a potential interest in exploring the application of AR in the surgical field among medical students. These findings of our study emphasize the need to align technological advancements with the expectations of both medical students and developers. By meeting the expectations of both groups, these technologies can be smoothly integrated into medical education.

This study highlights an interesting alignment in perspectives between medical students and developers, particularly in the situational scenario of explaining to a patient's caregiver. In this scenario, both groups showed potential interest in 3DP for conveying complex medical information to a patient's caregiver. Additionally, considering that students and developers in this study participated in creating patient-specific 3D-printed heart

models and that students gave group presentations with this technology, it can be inferred that personalized 3D-printed models are helpful in patients' caregiver communication. Previous studies demonstrated that the use of personalized 3DP models can further enhance patient understanding by providing tailored visual representations of individual patient anatomy and medical conditions [57,62,63].

This exploration of varying expectations will offer insights into how these technologies are anticipated to shape the future of medical training, patient care, and medical research. Several potential applications can be envisioned based on our research findings. In medical education for medical students and patients, VR, MR, and 3DP could be used for anatomy learning, medical research, simulation training, and procedural skills practice. VR can be used for virtual simulations of procedures like suturing, catheterization, and intubation, as well as clinical scenarios like patient assessments and diagnostic procedures. MR is expected to enhance anatomical learning and hands-on procedural training by combining virtual and real-world elements. It will overlay digital models onto physical specimens, which are generated from 3DP, and enable realistic simulations with them. Our speculation involves the use of AR, MR, and 3DP in surgical planning. Based on patient-specific medical imaging data, it is anticipated that surgeons will use patient-specific 3DP models to physically review and plan surgical approaches before the actual surgery. Alternatively, they may use AR and VR for surgical simulations to plan the procedure in advance. We also speculate that AR and MR will be used in specialties, such as neurosurgery, cardiovascular surgery, etc. Surgeons can use AR holograms of the heart or lungs to visualize complex cardiac anatomy during surgery and to orient and localize the target tumors or lesions. MR-guided interventions can facilitate minimally invasive procedures, such as transcatheter valve replacement, by providing real-time imaging guidance and navigation. VR and 3DP are expected to benefit patient care. We speculate that VR will help manage pain and reduce stress during treatment, while 3DP will allow for personalized models, improving the understanding of patient conditions and treatments.

While the majority of developers perceived the inherent capabilities of VR, AR, and MR technologies as strengths, an interesting aspect of our findings is that none of them mentioned providing experiences similar to real environments as a strength of VR technology or cited the refinement of information in AR technology (Multimedia Appendix 10). We infer that developers perceive providing experiences similar to real environments and refinement of information as technically challenging at present or as areas requiring further development and thus fail to recognize the benefits of each technology. In fact, modeling of environments, especially in the medical field, requires the creation of high-quality 3D objects [64]. Reaching highly realistic and natural photorealistic rendering and animations in full 3D can be exceedingly challenging and costly in terms of both time and money [65]. Therefore, we speculate that in addition to the advantages of each technology that developers currently recognize, additional improvement and development are needed for aspects of each technology that developers are not aware of at present.

This study identified a concern regarding developers' limited attention to health issues, although there is a high prevalence of computer vision syndrome as an occupational disease in the 21st century (Multimedia Appendix 10). Additionally, the focus of developers on hardware performance over health issues indicates concerning results where technical priorities overshadow user well-being. To address this, developers must adopt a more holistic approach that balances technical advancements with user safety. This includes integrating health considerations into the design and development process, implementing safety features, and conducting thorough user testing to mitigate health-related issues [66]. By prioritizing both technical excellence and user welfare, developers will enhance the overall ethical standards of these technologies and contribute to a safer and more responsible technological landscape.

Regarding 3DP, our results showed that developers perceived the practical aspect of manufacturing customized products as an advantage of 3DP over the creative aspect of new design possibilities. This finding is consistent with previous studies reporting that customization allows for printing parts with geometries tailored to each print, which can be particularly useful in patient-specific fabrications for personalized medicine, where the layout matches a specific patient's anatomy [67]. As a significant challenge, the developers in this study and several other studies recognized high manufacturing costs [68]. However, in general, 3DP has been applied in the medical field. Therefore, this study suggests the need for continued research and development efforts aimed at optimizing the cost-effectiveness of 3DP technology without compromising on its advantages.

Limitations

This study has several limitations. First, this study was conducted in a single institution with a relatively small sample size. Further studies should be conducted and compared across multiple medical schools. Second, this study was limited by the exclusive focus on first-year medical students and developers involved in the course. While this provided valuable insights into the perspectives of these specific groups, the exclusion of residents, fellows, and senior medical professionals may limit the generalizability and applicability of our findings. Participants from diverse backgrounds should be included in further studies. Third, owing to the voluntary nature of student participation in the course, participant selection was not conducted. Consequently, our study results may be influenced by the higher proportion of male individuals than female individuals in the student group, potentially resulting in a dominance of male perspectives in the outcomes. Fourth, students having difficulty distinguishing between VR, AR, and MR experiences may have influenced the accuracy of the self-reported engagement with these technologies. Future studies should consider incorporating educational interventions to enhance students' understanding of various immersive technologies before administering surveys on technology usage. Lastly, it was not possible to validate the instruments used in this study, and we used a limited number of questionnaire items to measure the levels of students' and developers' satisfaction with the elective course. Despite these limitations, this study might help to understand differences in

satisfaction levels between medical students and developers, as well as discrepancies in their perceptions of future technological advancements.

Conclusion

The roadblock for better integration of VR, AR, MR, and 3DP technologies in medical education is the gap in satisfaction levels and future anticipations between medical students and developers. Our study found that VR, AR, and 3DP technologies showed differences in satisfaction levels in the categories of esthetics and continuous use intention. In particular, in VR,

differences in satisfaction levels regarding reality (real world) emerged as a major obstacle to integration into medical education. Medical students and developers had different anticipations of the future use of technology regarding education, surgical planning, and surgery. Furthermore, insights from industry developers indicated that hardware performance poses a challenge for VR, AR, and MR, while high manufacturing cost is the primary concern for 3DP. Recognizing and understanding these discrepancies and current challenges can help developers tailor their strategies and innovations to better meet the expectations of technology users.

Acknowledgments

The authors would like to thank Jae Gun Kwak (Department of Thoracic and Cardiovascular Surgery, Seoul National University Children's Hospital, Seoul, Republic of Korea) for providing the computed tomography data and images from patients with congenital heart disease, and MEDICALIP Co, Ltd for offering 3D segmented images using 3D medical image processing software. This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

DHS (drdoogi@snu.ac.kr) and HJC (hjchoi@snu.ac.kr) are co-corresponding authors of this manuscript.

Data Availability

The data used or analyzed in this study are available from the corresponding author upon reasonable request.

Authors' Contributions

YHY made substantial contributions to conceptualization, data curation, formal analysis, investigation, methodology, resources, software, validation, visualization, writing—original draft, and writing—review and editing. DHS contributed to conceptualization, data curation, formal analysis, investigation, methodology, project administration, supervision, validation, and writing—review and editing. HJC contributed to conceptualization, methodology, project administration, supervision, formal analysis, validation, and writing—review and editing. All authors approved the final version of the manuscript for submission.

Conflicts of Interest

None declared.

Multimedia Appendix 1

The process of creating a 3D reconstruction from a patient's computed tomography scan.

[[MP4 File \(MP4 Video\), 92202 KB - xr_v1i1e54230_app1.mp4](#)]

Multimedia Appendix 2

The heart of a patient with an interrupted aortic arch.

[[MP4 File \(MP4 Video\), 32727 KB - xr_v1i1e54230_app2.mp4](#)]

Multimedia Appendix 3

The heart of a patient with Ebstein anomaly.

[[MP4 File \(MP4 Video\), 33538 KB - xr_v1i1e54230_app3.mp4](#)]

Multimedia Appendix 4

The heart of a patient with transposition of the great arteries.

[[MP4 File \(MP4 Video\), 15565 KB - xr_v1i1e54230_app4.mp4](#)]

Multimedia Appendix 5

The heart of a patient with major aortopulmonary collateral arteries.

[[MP4 File \(MP4 Video\), 30007 KB - xr_v1i1e54230_app5.mp4](#)]

Multimedia Appendix 6

A survey on satisfaction with virtual reality, augmented reality, and 3D printing technologies.

[[DOCX File , 28 KB - xr_v1i1e54230_app6.docx](#)]

Multimedia Appendix 7

The educational background of the software and content developers in this study.

[[DOCX File , 17 KB - xr_v1i1e54230_app7.docx](#)]

Multimedia Appendix 8

Average satisfaction differences in virtual reality, augmented reality, and 3D printing between students and developers.

[[DOCX File , 52 KB - xr_v1i1e54230_app8.docx](#)]

Multimedia Appendix 9

Medical students' (n=15) and developers' (n=26) anticipation of the use of technologies in various medical contexts within 5 years. The pie charts present percentages.

[[PNG File , 241 KB - xr_v1i1e54230_app9.png](#)]

Multimedia Appendix 10

Developers' perceptions of the advantages and current challenges of virtual reality, augmented reality, mixed reality, and 3D printing.

[[PNG File , 335 KB - xr_v1i1e54230_app10.png](#)]

References

1. Aliwi I, Schot V, Carrabba M, Duong P, Shievano S, Caputo M, et al. The role of immersive virtual reality and augmented reality in medical communication: a scoping review. *J Patient Exp* 2023 Jun 27;10:23743735231171562 [[FREE Full text](#)] [doi: [10.1177/23743735231171562](https://doi.org/10.1177/23743735231171562)] [Medline: [37441275](https://pubmed.ncbi.nlm.nih.gov/37441275/)]
2. Tasneem I, Ariz A, Bharti D, Haleem A, Javaid M, Bahl S. 3D printing technology and its significant applications in the context of healthcare education. *J Ind Intg Mgmt* 2021 May 25;08(01):113-130. [doi: [10.1142/S2424862221500159](https://doi.org/10.1142/S2424862221500159)]
3. Gerup J, Soerensen CB, Dieckmann P. Augmented reality and mixed reality for healthcare education beyond surgery: an integrative review. *Int J Med Educ* 2020 Jan 18;11:1-18 [[FREE Full text](#)] [doi: [10.5116/ijme.5e01.eb1a](https://doi.org/10.5116/ijme.5e01.eb1a)] [Medline: [31955150](https://pubmed.ncbi.nlm.nih.gov/31955150/)]
4. Radianti J, Majchrzak T, Fromm J, Wohlgenannt I. A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education* 2020 Apr;147(12):103778. [doi: [10.1016/j.compedu.2019.103778](https://doi.org/10.1016/j.compedu.2019.103778)]
5. Valls-Esteve A, Adell-Gómez N, Pasten A, Barber I, Munuera J, Krauel L. Exploring the potential of three-dimensional imaging, printing, and modeling in pediatric surgical oncology: a new era of precision surgery. *Children (Basel)* 2023 May 03;10(5):832 [[FREE Full text](#)] [doi: [10.3390/children10050832](https://doi.org/10.3390/children10050832)] [Medline: [37238380](https://pubmed.ncbi.nlm.nih.gov/37238380/)]
6. Venugopal JP, Subramanian AAV, Peatchimuthu J. The realm of metaverse: a survey. *Computer Animation & Virtual* 2023 Mar 02;34(5):e2150. [doi: [10.1002/cav.2150](https://doi.org/10.1002/cav.2150)]
7. Rokhsaritalemi S, Sadeghi-Niaraki A, Choi S. A review on mixed reality: current trends, challenges and prospects. *Applied Sciences* 2020 Jan 16;10(2):636. [doi: [10.3390/app10020636](https://doi.org/10.3390/app10020636)]
8. Venkatesan M, Mohan H, Ryan J, Schürch C, Nolan G, Frakes D, et al. Virtual and augmented reality for biomedical applications. *Cell Rep Med* 2021 Jul 20;2(7):100348 [[FREE Full text](#)] [doi: [10.1016/j.xcrm.2021.100348](https://doi.org/10.1016/j.xcrm.2021.100348)] [Medline: [34337564](https://pubmed.ncbi.nlm.nih.gov/34337564/)]
9. Sugimoto M. Extended reality (XR:VR/AR/MR), 3D printing, holography, A.I., radiomics, and online VR tele-medicine for precision surgery. In: Takenoshita S, Yasuhara H, editors. *Surgery and Operating Room Innovation*. Singapore: Springer; 2021:65-70.
10. Ghazi AE, Teplitz BA. Role of 3D printing in surgical education for robotic urology procedures. *Transl Androl Urol* 2020 Apr;9(2):931-941 [[FREE Full text](#)] [doi: [10.21037/tau.2020.01.03](https://doi.org/10.21037/tau.2020.01.03)] [Medline: [32420209](https://pubmed.ncbi.nlm.nih.gov/32420209/)]
11. Jiang H, Vimalasvaran S, Wang J, Lim K, Mogali S, Car L. Virtual reality in medical students' education: scoping review. *JMIR Med Educ* 2022 Feb 02;8(1):e34860 [[FREE Full text](#)] [doi: [10.2196/34860](https://doi.org/10.2196/34860)] [Medline: [35107421](https://pubmed.ncbi.nlm.nih.gov/35107421/)]
12. Karbasi Z, Niakan Kalhori S. Application and evaluation of virtual technologies for anatomy education to medical students: a review. *Med J Islam Repub Iran* 2020 Oct 30;34:163 [[FREE Full text](#)] [doi: [10.47176/mjiri.34.163](https://doi.org/10.47176/mjiri.34.163)] [Medline: [33816362](https://pubmed.ncbi.nlm.nih.gov/33816362/)]
13. Zhao J, Xu X, Jiang H, Ding Y. The effectiveness of virtual reality-based technology on anatomy teaching: a meta-analysis of randomized controlled studies. *BMC Med Educ* 2020 Apr 25;20(1):127 [[FREE Full text](#)] [doi: [10.1186/s12909-020-1994-z](https://doi.org/10.1186/s12909-020-1994-z)] [Medline: [32334594](https://pubmed.ncbi.nlm.nih.gov/32334594/)]
14. Tang Y, Chau K, Kwok A, Zhu T, Ma X. A systematic review of immersive technology applications for medical practice and education - trends, application areas, recipients, teaching contents, evaluation methods, and performance. *Educational Research Review* 2022 Feb;35(12):100429. [doi: [10.1016/j.edurev.2021.100429](https://doi.org/10.1016/j.edurev.2021.100429)]

15. Durrani S, Onyedimma C, Jarrah R, Bhatti A, Nathani KR, Bhandarkar AR, et al. The virtual vision of neurosurgery: how augmented reality and virtual reality are transforming the neurosurgical operating room. *World Neurosurg* 2022 Dec;168:190-201. [doi: [10.1016/j.wneu.2022.10.002](https://doi.org/10.1016/j.wneu.2022.10.002)] [Medline: [36208867](https://pubmed.ncbi.nlm.nih.gov/36208867/)]
16. Dhar P, Rocks T, Samarasinghe R, Stephenson G, Smith C. Augmented reality in medical education: students' experiences and learning outcomes. *Med Educ Online* 2021 Dec;26(1):1953953 [FREE Full text] [doi: [10.1080/10872981.2021.1953953](https://doi.org/10.1080/10872981.2021.1953953)] [Medline: [34259122](https://pubmed.ncbi.nlm.nih.gov/34259122/)]
17. Cellina M, Cè M, Ali M, Irmici G, Ibba S, Caloro E, et al. Digital twins: the new frontier for personalized medicine? *Applied Sciences* 2023 Jul 06;13(13):7940. [doi: [10.3390/app13137940](https://doi.org/10.3390/app13137940)]
18. Xie B, Liu H, Alghofaili R, Zhang Y, Jiang Y, Lobo F, et al. A review on virtual reality skill training applications. *Front Virtual Real* 2021 Apr 30;2(12):e1001940. [doi: [10.3389/frvir.2021.645153](https://doi.org/10.3389/frvir.2021.645153)]
19. Sánchez-Margallo J, Plaza de Miguel C, Fernández Anzules R, Sánchez-Margallo F. Application of mixed reality in medical training and surgical planning focused on minimally invasive surgery. *Front Virtual Real* 2021 Oct 28;2(12):e1001940. [doi: [10.3389/frvir.2021.692641](https://doi.org/10.3389/frvir.2021.692641)]
20. Lungu AJ, Swinkels W, Claesen L, Tu P, Egger J, Chen X. A review on the applications of virtual reality, augmented reality and mixed reality in surgical simulation: an extension to different kinds of surgery. *Expert Rev Med Devices* 2021 Jan 16;18(1):47-62. [doi: [10.1080/17434440.2021.1860750](https://doi.org/10.1080/17434440.2021.1860750)] [Medline: [33283563](https://pubmed.ncbi.nlm.nih.gov/33283563/)]
21. Verhey J, Haglin J, Verhey E, Hartigan D. Virtual, augmented, and mixed reality applications in orthopedic surgery. *Int J Med Robot* 2020 Apr;16(2):e2067 [FREE Full text] [doi: [10.1002/rcs.2067](https://doi.org/10.1002/rcs.2067)] [Medline: [31867864](https://pubmed.ncbi.nlm.nih.gov/31867864/)]
22. Pregowska A, Osial M, Dolega-Dolegowski D, Kolecki R, Proniewska K. Information and communication technologies combined with mixed reality as supporting tools in medical education. *Electronics* 2022 Nov 17;11(22):3778. [doi: [10.3390/electronics11223778](https://doi.org/10.3390/electronics11223778)]
23. Olatunji G, Osaghae O, Aderinto N. Exploring the transformative role of 3D printing in advancing medical education in Africa: a review. *Ann Med Surg (Lond)* 2023 Oct;85(10):4913-4919 [FREE Full text] [doi: [10.1097/MS9.0000000000001195](https://doi.org/10.1097/MS9.0000000000001195)] [Medline: [37811062](https://pubmed.ncbi.nlm.nih.gov/37811062/)]
24. Karakurt I, Lin L. 3D printing technologies: techniques, materials, and post-processing. *Current Opinion in Chemical Engineering* 2020 Jun;28:134-143. [doi: [10.1016/j.coche.2020.04.001](https://doi.org/10.1016/j.coche.2020.04.001)]
25. Dod G, Jibhakate R, Walke P. A review on 3D printing maxillofacial surgery: present work and future prospects. *Materials Today: Proceedings* 2023 Jun:49. [doi: [10.1016/j.matpr.2023.06.049](https://doi.org/10.1016/j.matpr.2023.06.049)]
26. Ullah M, Hamayun S, Wahab A, Khan SU, Rehman MU, Haq ZU, et al. Smart technologies used as smart tools in the management of cardiovascular disease and their future perspective. *Curr Probl Cardiol* 2023 Nov;48(11):101922. [doi: [10.1016/j.cpcardiol.2023.101922](https://doi.org/10.1016/j.cpcardiol.2023.101922)] [Medline: [37437703](https://pubmed.ncbi.nlm.nih.gov/37437703/)]
27. Yan Q, Dong H, Su J, Han J, Song B, Wei Q, et al. A review of 3D printing technology for medical applications. *Engineering* 2018 Oct;4(5):729-742. [doi: [10.1016/j.eng.2018.07.021](https://doi.org/10.1016/j.eng.2018.07.021)]
28. Cornejo J, Cornejo-Aguilar J, Vargas M, Helguero C, Milanezi de Andrade R, Torres-Montoya S, et al. Anatomical engineering and 3D printing for surgery and medical devices: international review and future exponential innovations. *Biomed Res Int* 2022;2022:6797745 [FREE Full text] [doi: [10.1155/2022/6797745](https://doi.org/10.1155/2022/6797745)] [Medline: [35372574](https://pubmed.ncbi.nlm.nih.gov/35372574/)]
29. Patra A, Pushpa N, Ravi K. Visualization in anatomy education. In: Abdel Meguid E, Mishall PL, Nation HL, Rea PM, editors. *Biomedical Visualisation. Advances in Experimental Medicine and Biology*, vol 1406. Cham: Springer; 2023:171-186.
30. Wickramasinghe N, Thompson BR, Xiao J. The opportunities and challenges of digital anatomy for medical sciences: narrative review. *JMIR Med Educ* 2022 May 20;8(2):e34687 [FREE Full text] [doi: [10.2196/34687](https://doi.org/10.2196/34687)] [Medline: [35594064](https://pubmed.ncbi.nlm.nih.gov/35594064/)]
31. Wixted CM, Peterson JR, Kadakia RJ, Adams SB. Three-dimensional printing in orthopaedic surgery: current applications and future developments. *JAAOS Glob Res Rev* 2021 Apr 20;5(4):e20.00230-e20.00211. [doi: [10.5435/jaaosglobal-d-20-00230](https://doi.org/10.5435/jaaosglobal-d-20-00230)]
32. Yun YH, Jo DH, Jeon SK, Kwon HY, Jeon YM, Shin DH, et al. The impact of the modified schedules of anatomy education on students' performance and satisfaction: Responding to COVID-19 pandemic in South Korea. *PLoS One* 2022 Apr 11;17(4):e0266426 [FREE Full text] [doi: [10.1371/journal.pone.0266426](https://doi.org/10.1371/journal.pone.0266426)] [Medline: [35404971](https://pubmed.ncbi.nlm.nih.gov/35404971/)]
33. Pereda-Nuñez A, Manresa M, Webb SS, Pineda B, Espuña M, Ortega M, et al. Pelvic + Anatomy: A new interactive pelvic anatomy model. Prospective randomized control trial with first-year midwife residents. *Anat Sci Educ* 2023 Jun 13;16(5):843-857. [doi: [10.1002/ase.2304](https://doi.org/10.1002/ase.2304)] [Medline: [37312278](https://pubmed.ncbi.nlm.nih.gov/37312278/)]
34. Yan X, Zhu Y, Fang L, Ding P, Fang S, Zhou J, et al. Enhancing medical education in respiratory diseases: efficacy of a 3D printing, problem-based, and case-based learning approach. *BMC Med Educ* 2023 Jul 17;23(1):512 [FREE Full text] [doi: [10.1186/s12909-023-04508-6](https://doi.org/10.1186/s12909-023-04508-6)] [Medline: [37461009](https://pubmed.ncbi.nlm.nih.gov/37461009/)]
35. O'Connor M, Stowe J, Potocnik J, Giannotti N, Murphy S, Rainford L. 3D virtual reality simulation in radiography education: The students' experience. *Radiography (Lond)* 2021 Feb;27(1):208-214 [FREE Full text] [doi: [10.1016/j.radi.2020.07.017](https://doi.org/10.1016/j.radi.2020.07.017)] [Medline: [32800641](https://pubmed.ncbi.nlm.nih.gov/32800641/)]
36. Dennler C, Bauer DE, Scheibler A, Spirig J, Götschi T, Fürnstahl P, et al. Augmented reality in the operating room: a clinical feasibility study. *BMC Musculoskelet Disord* 2021 May 18;22(1):451 [FREE Full text] [doi: [10.1186/s12891-021-04339-w](https://doi.org/10.1186/s12891-021-04339-w)] [Medline: [34006234](https://pubmed.ncbi.nlm.nih.gov/34006234/)]
37. Paternò F, Wulf V. *New Perspectives in End-User Development*. Cham: Springer; 2017.

38. Shah H, Dingley S, Golder P. Bridging the culture gap between users and developers. *J Syst Manag* 1994;45(7):18-21.
39. Subramanyam R, Weisstein FL, Krishnan MS. User participation in software development projects. *Commun. ACM* 2010 Mar 01;53(3):137-141. [doi: [10.1145/1666420.1666455](https://doi.org/10.1145/1666420.1666455)]
40. Melone N. A theoretical assessment of the user-satisfaction construct in information systems research. *Management Science* 1990 Jan 21;36(1):76-91. [doi: [10.1287/mnsc.36.1.76](https://doi.org/10.1287/mnsc.36.1.76)]
41. Ives B, Olson M, Baroudi J. The measurement of user information satisfaction. *Commun. ACM* 1983 Oct 21;26(10):785-793. [doi: [10.1145/358413.358430](https://doi.org/10.1145/358413.358430)]
42. Au N, Ngai EWT, Cheng TCE. Extending the understanding of end user information systems satisfaction formation: An equitable needs fulfillment model approach. *MIS Quarterly* 2008;32(1):43. [doi: [10.2307/25148828](https://doi.org/10.2307/25148828)]
43. Briggs R, Reinig B, Vreede G. The yield shift theory of satisfaction and its application to the IS/IT domain. *JAIS* 2008 May 21;9(5):267-293. [doi: [10.17705/1jais.00160](https://doi.org/10.17705/1jais.00160)]
44. Xiao W, Wang M, Mo J. Factors influencing college teachers' adoption of live online teaching: a conditional process model of technology acceptance, user satisfaction and privacy concerns. *Front Psychol* 2023 Dec;14(12):1293879 [FREE Full text] [doi: [10.3389/fpsyg.2023.1293879](https://doi.org/10.3389/fpsyg.2023.1293879)] [Medline: [38268812](https://pubmed.ncbi.nlm.nih.gov/38268812/)]
45. Elshami W, Taha M, Abuzaid M, Saravanan C, Al Kawas S, Abdalla M. Satisfaction with online learning in the new normal: perspective of students and faculty at medical and health sciences colleges. *Med Educ Online* 2021 Dec;26(1):1920090 [FREE Full text] [doi: [10.1080/10872981.2021.1920090](https://doi.org/10.1080/10872981.2021.1920090)] [Medline: [33974523](https://pubmed.ncbi.nlm.nih.gov/33974523/)]
46. Jedwab RM, Manias E, Redley B, Dobroff N, Hutchinson AM. Impacts of technology implementation on nurses' work motivation, engagement, satisfaction and well-being: A realist review. *J Clin Nurs* 2023 Sep 21;32(17-18):6037-6060. [doi: [10.1111/jocn.16730](https://doi.org/10.1111/jocn.16730)] [Medline: [37082879](https://pubmed.ncbi.nlm.nih.gov/37082879/)]
47. van Lente H. Expected behavior. In: Verbeek PP, Slob A, editors. *User Behavior and Technology Development*, vol 20. Dordrecht: Springer; 2006:211-219.
48. Arthur WB. Competing technologies, increasing returns, and lock-in by historical events. *The Economic Journal* 1989 Mar;99(394):116. [doi: [10.2307/2234208](https://doi.org/10.2307/2234208)]
49. Yi WS, Rouhi AD, Duffy CC, Ghanem YK, Williams NN, Dumon KR. A systematic review of immersive virtual reality for nontechnical skills training in surgery. *J Surg Educ* 2024 Jan;81(1):25-36. [doi: [10.1016/j.jsurg.2023.11.012](https://doi.org/10.1016/j.jsurg.2023.11.012)] [Medline: [38036388](https://pubmed.ncbi.nlm.nih.gov/38036388/)]
50. Cheng K, Tsai C. Affordances of augmented reality in science learning: suggestions for future research. *J Sci Educ Technol* 2012 Aug 3;22(4):449-462. [doi: [10.1007/s10956-012-9405-9](https://doi.org/10.1007/s10956-012-9405-9)]
51. Hemidli N. Introduction to UI/UX design: key concepts and principles. Academia. URL: https://www.academia.edu/98036432/Introduction_to_UI_UX_Design_Key_Concepts_and_Principles [accessed 2024-04-27]
52. Pujol S, Baldwin M, Nassiri J, Kikinis R, Shaffer K. Using 3D modeling techniques to enhance teaching of difficult anatomical concepts. *Acad Radiol* 2016 Apr;23(4):507-516 [FREE Full text] [doi: [10.1016/j.acra.2015.12.012](https://doi.org/10.1016/j.acra.2015.12.012)] [Medline: [26897601](https://pubmed.ncbi.nlm.nih.gov/26897601/)]
53. Sweeney K, Hayes JA, Chiavaroli N. Does spatial ability help the learning of anatomy in a biomedical science course? *Anat Sci Educ* 2014 Nov 12;7(4):289-294. [doi: [10.1002/ase.1418](https://doi.org/10.1002/ase.1418)] [Medline: [24227747](https://pubmed.ncbi.nlm.nih.gov/24227747/)]
54. Langlois J, Bellemare C, Toulouse J, Wells GA. Spatial abilities training in anatomy education: a systematic review. *Anat Sci Educ* 2020 Jan 03;13(1):71-79. [doi: [10.1002/ase.1873](https://doi.org/10.1002/ase.1873)] [Medline: [30839169](https://pubmed.ncbi.nlm.nih.gov/30839169/)]
55. Georgiou Y, Kyza EA. Relations between student motivation, immersion and learning outcomes in location-based augmented reality settings. *Comput Hum Behav* 2018 Dec;89:173-181. [doi: [10.1016/j.chb.2018.08.011](https://doi.org/10.1016/j.chb.2018.08.011)]
56. Zhao H, Khan A. The students' flow experience with the continuous intention of using online english platforms. *Front Psychol* 2021 Dec;12(12):807084 [FREE Full text] [doi: [10.3389/fpsyg.2021.807084](https://doi.org/10.3389/fpsyg.2021.807084)] [Medline: [35211057](https://pubmed.ncbi.nlm.nih.gov/35211057/)]
57. Ye Z, Dun A, Jiang H, Nie C, Zhao S, Wang T, et al. The role of 3D printed models in the teaching of human anatomy: a systematic review and meta-analysis. *BMC Med Educ* 2020 Sep 29;20(1):335 [FREE Full text] [doi: [10.1186/s12909-020-02242-x](https://doi.org/10.1186/s12909-020-02242-x)] [Medline: [32993608](https://pubmed.ncbi.nlm.nih.gov/32993608/)]
58. Schlegel L, Ho M, Fields J, Backlund E, Pugliese R, Shine K. Standardizing evaluation of patient-specific 3D printed models in surgical planning: development of a cross-disciplinary survey tool for physician and trainee feedback. *BMC Med Educ* 2022 Aug 12;22(1):614 [FREE Full text] [doi: [10.1186/s12909-022-03581-7](https://doi.org/10.1186/s12909-022-03581-7)] [Medline: [35953840](https://pubmed.ncbi.nlm.nih.gov/35953840/)]
59. Youn JK, Park SJ, Choi Y, Han J, Ko D, Byun J, et al. Application of 3D printing technology for pre-operative evaluation, education and informed consent in pediatric retroperitoneal tumors. *Sci Rep* 2023 Jan 30;13(1):1671 [FREE Full text] [doi: [10.1038/s41598-023-28423-4](https://doi.org/10.1038/s41598-023-28423-4)] [Medline: [36717595](https://pubmed.ncbi.nlm.nih.gov/36717595/)]
60. Cofano F, Di Perna G, Bozzaro M, Longo A, Marengo N, Zenga F, et al. Augmented reality in medical practice: from spine surgery to remote assistance. *Front Surg* 2021 Dec;8(12):657901 [FREE Full text] [doi: [10.3389/fsurg.2021.657901](https://doi.org/10.3389/fsurg.2021.657901)] [Medline: [33859995](https://pubmed.ncbi.nlm.nih.gov/33859995/)]
61. Jud L, Fotouhi J, Andronic O, Aichmair A, Osgood G, Navab N, et al. Applicability of augmented reality in orthopedic surgery - a systematic review. *BMC Musculoskelet Disord* 2020 Feb 15;21(1):103 [FREE Full text] [doi: [10.1186/s12891-020-3110-2](https://doi.org/10.1186/s12891-020-3110-2)] [Medline: [32061248](https://pubmed.ncbi.nlm.nih.gov/32061248/)]

62. Zhuang Y, Zhou M, Liu S, Wu J, Wang R, Chen C. Effectiveness of personalized 3D printed models for patient education in degenerative lumbar disease. *Patient Educ Couns* 2019 Oct;102(10):1875-1881. [doi: [10.1016/j.pec.2019.05.006](https://doi.org/10.1016/j.pec.2019.05.006)] [Medline: [31113688](https://pubmed.ncbi.nlm.nih.gov/31113688/)]
63. Meyer-Szary J, Luis MS, Mikulski S, Patel A, Schulz F, Tretiakow D, et al. The role of 3D printing in planning complex medical procedures and training of medical professionals-cross-sectional multispecialty review. *Int J Environ Res Public Health* 2022 Mar 11;19(6):3331 [FREE Full text] [doi: [10.3390/ijerph19063331](https://doi.org/10.3390/ijerph19063331)] [Medline: [35329016](https://pubmed.ncbi.nlm.nih.gov/35329016/)]
64. Baniyasi T, Ayyoubzadeh SM, Mohammadzadeh N. Challenges and practical considerations in applying virtual reality in medical education and treatment. *Oman Med J* 2020 May 19;35(3):e125-e125 [FREE Full text] [doi: [10.5001/omj.2020.43](https://doi.org/10.5001/omj.2020.43)] [Medline: [32489677](https://pubmed.ncbi.nlm.nih.gov/32489677/)]
65. Debarba HG, Montagud M, Chagué S, Herrero JG, Lacosta I, Langa SF, et al. Content format and quality of experience in virtual reality. *Multimed Tools Appl* 2022 Mar 09;83(15):46481-46506. [doi: [10.1007/S11042-022-12176-9](https://doi.org/10.1007/S11042-022-12176-9)]
66. Maroungkas A, Troussas C, Krouska A, Sgouropoulou C. Virtual reality in education: a review of learning theories, approaches and methodologies for the last decade. *Electronics* 2023 Jun 26;12(13):2832. [doi: [10.3390/electronics12132832](https://doi.org/10.3390/electronics12132832)]
67. Arefin A, Khatri N, Kulkarni N, Egan P. Polymer 3D printing review: materials, process, and design strategies for medical applications. *Polymers (Basel)* 2021 May 06;13(9):e1001940 [FREE Full text] [doi: [10.3390/polym13091499](https://doi.org/10.3390/polym13091499)] [Medline: [34066639](https://pubmed.ncbi.nlm.nih.gov/34066639/)]
68. Tian Y, Chen C, Xu X, Wang J, Hou X, Li K, et al. A review of 3D printing in dentistry: technologies, affecting factors, and applications. *Scanning* 2021 Dec;2021(12):9950131 [FREE Full text] [doi: [10.1155/2021/9950131](https://doi.org/10.1155/2021/9950131)] [Medline: [34367410](https://pubmed.ncbi.nlm.nih.gov/34367410/)]

Abbreviations

- 3DP:** 3D printing
- AI:** artificial intelligence
- AR:** augmented reality
- CHD:** congenital heart disease
- MR:** mixed reality
- VR:** virtual reality

Edited by T Leung; submitted 02.11.23; peer-reviewed by M Hirota, K Eilbeck; comments to author 21.02.24; revised version received 12.03.24; accepted 25.04.24; published 07.05.24.

Please cite as:

Yun YH, Shin DH, Choi HJ

Perspectives of Medical Students and Developers Regarding Virtual Reality, Augmented Reality, Mixed Reality, and 3D Printing Technologies: Survey Study

JMIR XR Spatial Comput 2024;1:e54230

URL: <https://xr.jmir.org/2024/1/e54230>

doi: [10.2196/54230](https://doi.org/10.2196/54230)

PMID:

©Young Hyun Yun, Dong Hoon Shin, Hyung Jin Choi. Originally published in JMIR XR and Spatial Computing (<https://xr.jmir.org>), 07.05.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR XR and Spatial Computing, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Original Paper

Brain Activation During Virtual Reality Symptom Provocation in Obsessive-Compulsive Disorder: Proof-of-Concept Study

Martine J van Bennekom¹, MD, PhD; Guido van Wingen¹, Prof Dr; Willem Benjamin Bruin¹, MSc; Judy Luigjes^{1*}, PhD; Damiaan Denys^{1*}, MD, Prof Dr

Adult Psychiatry, Amsterdam UMC location University of Amsterdam, Amsterdam, Netherlands

* these authors contributed equally

Corresponding Author:

Martine J van Bennekom, MD, PhD

Adult Psychiatry

Amsterdam UMC location University of Amsterdam

Meibergdreef 9

Amsterdam, 1105 AZ

Netherlands

Phone: 31 0208913656

Email: m.j.vanbennekom@amsterdamumc.nl

Abstract

Background: Obsessive-compulsive disorder (OCD) is a psychiatric disorder characterized by obsessions and compulsions. We previously showed that a virtual reality (VR) game can be used to provoke and measure anxiety and compulsions in patients with OCD. Here, we investigated whether this VR game activates brain regions associated with symptom provocation.

Objective: In this study, we aim to investigate the neural regions that are activated in patients with OCD when they are interactively confronted with a symptom-provoking event and when they are performing compulsive actions in VR.

Methods: In a proof-of-concept study, we investigated brain activation in response to the VR game in 9 patients with OCD and 9 healthy controls. Participants played the VR game while regional changes in blood oxygenation were measured using functional magnetic resonance imaging. We investigated brain activation in relation to OCD-related events and virtual compulsions in the VR game. Due to low statistical power because of the sample size, we also reported results at trend significance level with a threshold of $P < .10$. Additionally, we investigated correlations between OCD severity and brain activation.

Results: We observed a trend for increased activation in the left amygdala ($P = .07$) upon confrontation with OCD-related events and for increased activation in the bilateral amygdala ($P = .06$ and $P = .09$) and right insula ($P = .09$) when performing virtual compulsive actions in patients with OCD compared to healthy controls, but this did not attain statistical significance. The amygdala and insula activation did not correlate with OCD severity.

Conclusions: The findings of this proof-of-concept study indicate that VR elicits brain activation in line with previous provocation studies. Our findings need to be replicated in a study with a larger sample size. VR may be used as an innovative and unique method of interactive symptom provocation in future neuroimaging studies.

Trial Registration: Netherlands Trial Register NTR6420; <https://onderzoekmetmensen.nl/nl/trial/25755>

(*JMIR XR Spatial Comput* 2024;1:e47468) doi:[10.2196/47468](https://doi.org/10.2196/47468)

KEYWORDS

virtual reality; obsessive-compulsive disorder; VR; symptom provocation; MRI; neuroimaging; OCD

Introduction

Obsessive-compulsive disorder (OCD) is a chronic, debilitating disorder characterized by obsessions, recurring involuntary thoughts that are frequently linked to compulsions—mental or physical acts to control provoked emotions of fear or restlessness. The obsessions and compulsions are often

accompanied by feelings of anxiety and uncertainty and cause a high level of suffering [1]. OCD has a 2%-3% lifetime prevalence and is associated with significant impairment in social and occupational functioning [2].

An OCD diagnosis is usually based on an interpretation of clinical signs and symptoms as retrospectively expressed by the patient. Assessment by a clinician while patients are actually

experiencing symptoms in the consulting room may provide a more realistic image of the symptoms and improve the diagnostic process. This can be achieved by symptom provocation [3].

Virtual reality (VR) is one way of achieving symptom provocation in patients with OCD. There are numerous examples of studies that have investigated the use of VR to provoke OCD symptoms in order to improve an OCD diagnosis or provide targeted treatment. For example, Laforest et al [4] showed that exposure to a virtual contaminated toilet in a VR immersion chamber led to an increase in anxiety and heart rate in patients with OCD with contamination fear compared to that in healthy controls.

Furthermore, in a systematic review and meta-analysis by Dehghan et al [5], it was found that VR environments were capable of significantly increasing anxiety, disgust, uncertainty, washing urges, time spent on checking, and the number of checks in patients with OCD compared to healthy controls.

In 2 former studies, we investigated an interactive VR game designed to provoke and assess OCD symptoms in a controlled and standardized way [6,7]. Figures 1 and 2 show a schematic outline and screenshots from the VR game. The VR game is designed to actively confront patients with OCD-related events

in a standard household environment. It is a first-person-perspective game composed of video images of an actual house. Patients are asked to carefully check the house, which is left behind in a hurry by a friend. They walk through the house in a preset order and are confronted with 15 OCD-related events (eg, turning off the gas stove). Patients are asked to solve these events and subsequently check or repeat the events as often as desired (for full details, see van Bennekom et al [7]). We showed that this VR game, when played on a laptop screen, was able to provoke higher levels of anxiety and virtual compulsions in patients with OCD than in healthy controls [6,7].

In this study, we modified the VR game to enable performance inside a functional magnetic resonance imaging (fMRI) scanner. In contrast to traditional “passive” fMRI symptom provocation tasks mostly using images, written verbal stimuli, emotional faces, or neurocognitive tasks with emotional interference [8,9], this VR game is interactive and realistic and therefore actively immerses patients whilst inside the scanner. This allows us to gain insight in to blood oxygenation level-dependent (BOLD) derived brain activation while patients are confronted with OCD-related events and while they perform virtual compulsive actions. To our knowledge, this is the first study using a VR game with fMRI for symptom provocation in OCD.

Figure 1. A 3D map of the house indicating obsessive-compulsive disorder-related items. 1: locking the gate (start); 2: locking the front door (start); 3: switching off the television; 4: extinguishing the candle; 5: organizing pencils; 6: closing the window; 7: cleaning the breakfast table; 8: turning off the gas stove; 9: organizing the cans; 10: cleaning the sink; 11: hand-washing after using the toilet; 12: switching off the flat iron; 13: organizing hazardous substances; 14: locking the front door (end); and 15: locking the gate (end).



Figure 2. Screenshots from the virtual reality game.



Recent meta-analyses of fMRI, positron emission tomography, and single-photon emission computed tomography studies underline several brain regions involved in the pathophysiology of OCD. Abnormalities in cortico-striato-thalamo-cortical pathways—circuits connecting the cortex, striatum, basal ganglia, and thalamus—are involved in the pathophysiological substrate [10]. In a recent meta-analysis of fMRI, positron emission tomography, and single-photon emission computed tomography studies conducted by Thorsen et al [9], brain activation during symptom provocation was compared between patients with OCD and healthy controls. They found higher levels of activation in the bilateral amygdala, right putamen, orbitofrontal cortex (OFC) extending into the anterior cingulate cortex (ACC) and ventromedial prefrontal cortex, and middle temporal and left inferior occipital cortices during emotional processing in patients than in healthy controls. In patients with OCD with a higher rate of comorbidity with anxiety or mood disorders, they found more pronounced activation in the right putamen, amygdala, and insula. Another preceding smaller meta-analysis of neuroimaging symptom provocation studies in OCD, conducted by Rotge et al [11], also found an increased likelihood of activation in 19 clusters in patients with OCD compared to healthy controls. These included the OFC, ACC, precuneus, and thalamus. Although paradigms have been developed to induce the urge to check in patients with OCD [12], to our knowledge, no provocation procedures to induce actual checking behavior have been applied in fMRI studies before.

Because our VR game represents a new and innovative technique for fMRI symptom provocation, we decided to perform a proof-of-concept study with a limited sample size. In this study, we aim to investigate the neural regions that are activated in patients with OCD when they are interactively confronted with a symptom-provoking event and when they are

performing compulsive actions in VR. Moreover, we aim to investigate whether activation in these regions is related to OCD symptom severity. We hypothesized that (1) playing the VR game inside a fMRI scanner would lead to increased brain activity within the OFC, ACC, amygdala, right putamen, and right insula in patients with OCD compared to that in healthy controls, and (2) a positive correlation exists between the degree of brain activation and the severity of OCD in patients.

Methods

Participants

We recruited 9 patients with OCD from December 2017 to March 2020 at the Psychiatric Outpatient Department of Amsterdam University Medical Center by means of information letters provided by their treating clinicians. Patients were also recruited through the Dutch OCD website Dwang.eu [13]. This sample size is in line with recommendations for proof-of-concept fMRI studies [14]. All included patients had a primary diagnosis of OCD, as determined by a psychiatrist and confirmed by the Mini-International Neuropsychiatric Interview in accordance with the DSM-IV (Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition) criteria [15]. We aimed to assess a clinically relevant group of patients with OCD including those with (mild to moderate) comorbid psychiatric disorders, under the condition that OCD was the primary diagnosis. We recruited 9 age- and gender-matched healthy controls through advertisements at the Amsterdam University Medical Center and by emailing individuals who formerly participated in research projects at our department. The healthy controls were free of any current mental disorders, as validated with the Mini-International Neuropsychiatric Interview. We excluded subjects with a history of severe neurological or cardiovascular disorders, psychotic disorder,

bipolar disorder, intellectual disability, and alcohol or substance abuse during the last 6 months. Furthermore, the use of medication potentially influencing cerebral blood flow, uncorrected hearing or vision problems, and irregular sleep/wake rhythm were exclusion criteria, as well as other contraindications for scanning with a magnetic resonance imaging (MRI) scanner.

Ethical Considerations

The study was approved by the Medical Ethics Committee of the Academic Medical Center of the University of Amsterdam (case number NL59652.018.16). All participants provided written informed consent before enrollment.

Procedure

The procedure of fMRI scanning was carried out at the Spinoza Centre for Neuroimaging, Amsterdam, the Netherlands. On the test day, trained clinical researchers obtained clinical and demographic data using questionnaires. After that, participants practiced controlling the VR game through manual button boxes in a mock scanner. For baseline measurements, they first watched a calming movie with nature scenes inside the scanner. Finally, they played the VR game during an fMRI scanning session. Trained technicians at the Spinoza Centre for Neuroimaging performed the scanning procedure in the presence of a trained researcher.

Patient and Public Involvement

Patients or the public were not involved in the design, conduct, reporting, or dissemination plans of our research.

Assessments

Clinical Data

Trained clinical researchers assessed OCD severity using the Yale-Brown Obsessive Compulsive Scale (Y-BOCS) and OCD subtype using the related Y-BOCS Symptom Checklist (Y-BOCS-SC) [16], in combination with an expert's opinion. They measured anxiety and depression symptoms with the Hamilton Rating Scales for anxiety [17] and depression [18]. Finally, the sense of presence was measured with the Igroup presence questionnaire [19].

VR Game

The setup of the VR game is described and illustrated in detail in our pilot study [7]. In short, it concerned a first-person-perspective video game based in a house with 15 OCD-related events. Participants walked a set route through the house and were confronted with all these events in a preset order. At every event, after confrontation, participants were asked if they wanted to correct and then check an event, or if they wanted to proceed to the next event without intervening. Checks could be repeated as often as desired. At each event, participants rated their emotional responses including anxiety, tension, uncertainty, and urge to control on a digital 0-10 visual analog scale (VAS) after confrontation, correction, and checking. The VR game's output scores included the VAS scores and the number of virtual compulsive actions performed.

For this study, we edited the output data of the VR game to allow communication with the fMRI scanner. After 35 minutes, both the game and scanning process were automatically stopped.

Participants could see the white projection screen behind the head through a mirror fixed at a 45° angle to the head coil (standard MRI equipment). The VR game provides an immersive virtual reality "feel" because it has a first-person perspective and is projected close to the eyes in the scanner. The participant operated the VR game by means of 2 manual button boxes.

Acquisition of Images and Preprocessing

MRI scanning was performed using a 3.0T MRI scanner (Philips) using a 32-channel SENSE head coil. Scanning included a high-resolution T₁-weighted structural scan for anatomical reference (repetition time=6.9 milliseconds, echo time=3.1 milliseconds, voxel size=1.20 mm isotropic, flip angle=8°, and 150 transverse slices). Additionally, at least 496 (range 496-883) BOLD scans were acquired using a T₂*-weighted gradient multiecho echoplanar imaging sequence [20], with the following parameters: repetition time=2375 milliseconds, echo time=9/26.4/43.8 milliseconds, flip angle=76.1°, field of view=224 × 224 × 122 mm³, voxel size=2.8 × 2.8 × 3.0 mm³, matrix size=76 × 73, slice thickness=3 mm, slice gap=0.3 mm, number of slices=37, acquired in foot-head order. There was a maximum time frame of 35 minutes for playing the VR game inside the scanner.

We performed imaging analysis using Statistical Parametric Mapping (version 12; Wellcome Trust Centre for Neuroimaging). Data preprocessing consisted of realignment of images with respect to the middle volume, slice timing correction, coregistration of echoplanar imaging data to structural T₁ data, normalization to Montreal Neurological Institute space (3 mm isotropic), and spatial smoothing using an 6-mm full width at half maximum Gaussian kernel. We checked for motion artifacts; for a patient with OCD, we had to omit the final 25% of the VR game scans, due to excessive motion artifacts (ie, >5-mm framewise displacement).

Data Processing and Statistical Analysis

Clinical and VR Game Data

Demographic, clinical, and VR game data were analyzed using SPSS (version 26; IBM Corp). The VAS score of each emotional response upon confrontation with an OCD-related item was averaged for the 15 items. We performed Bonferroni correction to correct for testing of multiple emotional responses. Because of the small sample size, nonparametric tests were used to compare patients with healthy controls. We used the Mann-Whitney *U* test to compare continuous data (age and emotional responses) and Fisher exact tests for comparing categorical data (sex, nationality, schooling, and number of compulsions), including categorized questionnaire scores, because original scores did not qualify as continuous due to their limited distribution. Furthermore, in the group of patients with OCD, we calculated the reduction in emotional responses by subtracting the VAS score after the last compulsive action from the VAS score at confrontation. We used a 1-sample Wilcoxon signed rank test to assess the reduction in emotional responses after performing compulsive actions. The α value was set at .05 for significance.

Neuroimaging Data

Functional MRI data were analyzed using Statistical Parametric Mapping software (version 12) [21]. We performed individual subject analyses within the context of the general linear model, using delta functions convolved with a canonical hemodynamic response function to model events of interest. To enable this first-level analysis, we subdivided the events in the game in confrontation, correction, checking and, VAS rating events (Figure 3), which were contrasted with short time frames in the game during which no specific events took place. This resulted in a total of 10 regressors.

On the second-level between-group comparison, we conducted an independent samples *t* test to determine whether the OCD-related events in the VR game influenced brain activation differently between patients with OCD and healthy controls.

Figure 3. Events in the virtual reality game. VAS: visual analog scale.



Results

Demographic and Clinical Data

Demographic and clinical data of the study participants are shown in Table 1. Patients showed significantly more obsessive-compulsive and depressive symptoms; however, anxiety symptoms (assessed using the Hamilton Rating Scale for Anxiety) and mean scores of the Igroup Presence Questionnaire did not categorically differ significantly between patients and healthy controls ($P=.21$ and $P=.17$, respectively).

We investigated group interactions using a priori regions of interest (ROIs). We defined the bilateral amygdala, OFC, ACC, right putamen, and right insula as a priori ROIs. We used a threshold of 0.01 (0.05 divided by 5; corrected for multiple ROIs) for significance. To accommodate the low statistical power due to the small sample size, we also reported results at a trend significance level with a threshold of $P<.10$. We corrected for multiple comparisons at the voxel level (family-wise error) using a small-volume correction for ROIs, which were based on the automatic anatomical labeling atlas [22], using the WFU Pickatlas tool [23]. To determine correlations of Y-BOCS scores with fMRI data in SPSS, we used Marsbar [24] to extract parameter estimates from the bilateral amygdala and right insula in patients with OCD. To determine correlations of the fMRI data with the Y-BOCS scores, the Spearman correlation coefficient was used.

Patients with OCD had a mean Y-BOCS score of 23, which indicates moderate symptom severity. All patients had symptoms from multiple OCD dimensions. The most common dominant dimensions included perfectionism or symmetry for 44.4% ($n=4$) and taboo thoughts (aggressive or sexual intrusions) for 33.3% ($n=3$) of patients with OCD. Five patients with OCD were treated with a selective serotonin reuptake inhibitor (SSRI) or serotonin and norepinephrine reuptake inhibitor (SNRI), and 4 patients were unmedicated. Four patients experienced comorbid disorders including generalized anxiety disorder, depression, and social anxiety.

Table 1. Demographic and clinical data of patients with obsessive-compulsive disorder and healthy controls.

Characteristics	Patients (n=9)	Controls (n=9)	<i>P</i> value
Age (years), mean (SD)	29 (8.0)	29 (8.5)	.97
Male sex, n (%)	4 (44)	4 (44)	>.99
Dutch nationality, n (%)	8 (89)	9 (100)	>.99
Tertiary education, n (%)	3 (33)	5 (56)	.64
HAM-A ^a score, mean (SD)	12 (7.5)	1 (2.0)	.21
HAM-D ^b , mean (SD)	11 (4.5)	1 (2.1)	.002
Y-BOCS ^c score, mean (SD)	23 (2.8)	0 (0)	<.001
IPQ ^d score, mean (SD)	1.97 (0.96)	1.53 (0.75)	.17

^aHAM-A: Hamilton Rating Scale for Anxiety.

^bHAM-D: Hamilton Rating Scale for Depression.

^cY-BOCS: Yale-Brown Obsessive Compulsive Scale.

^dIPQ: Igroup Presence Questionnaire.

VR Game Data

The provoked emotional responses when playing the VR game are shown in Table 2. These represent the difference in mean VAS scores at confrontation over all 15 items and VAS scores

at the baseline measurement. Playing the VR game provoked significantly more anxiety, but not tension, uncertainty, and an urge to control in patients with OCD compared to healthy controls. Furthermore, patients with OCD showed significantly more compulsive behavior in the VR game than healthy controls;

patients performed a mean of 0.46 (SE 0.14) compulsions per event, healthy controls performed a mean of 0.07 (SE 0.02) compulsions per event ($P=.03$). Finally, in patients with OCD, we found a significant reduction in anxiety (mean 1.54, SE 0.60;

$P=.001$), unrest (mean 3.09, SE 0.77; $P=.008$), and uncertainty (mean 1.72, SE 0.61; $P=.01$) but not in the urge to control (mean 2.16, SE 0.86; $P=.02$) after performing virtual compulsive actions.

Table 2. Provoked emotional responses during the virtual reality game measured using the visual analog scale (VAS).

	VAS scores of patients with obsessive-compulsive disorder (n=9), mean (SE)	VAS scores of controls (n=9), mean (SE)	U value	P value
Change ^a in anxiety	1.01 (0.38)	0.13 (0.30)	12.0	.01
Change in tension	0.78 (0.72)	0.21 (0.35)	36.0	.73
Change in uncertainty	1.47 (0.57)	-0.03 (0.19)	19.0	.06
Change in the urge to control	1.58 (0.63)	1.31 (0.37)	38.0	.86

^aDifference between scores at baseline and at confrontation.

Neuroimaging Data

Since 4 patients were unable to finish the VR game within 35 minutes, patients with OCD were exposed to a mean total number of 13.89 (SD 1.27) events during the VR game scan, whereas all healthy controls were exposed to all 15 (SD 0) events. After correction for multiple comparisons, there were no significant differences in brain activation between patients with OCD and healthy controls when playing the VR game. However, during confrontation with the OCD-related events in the game, a larger increase in left amygdala activity was observed in patients with OCD than in healthy controls at the trend level (Figure 4; peak voxels: x, y, and z=-27, -4, and -25;

$T=3.24$; $P_{fwe,svc}=.07$). When performing the virtual compulsive actions, a larger increase in left amygdala (Figure 5A; peak voxels: x, y, and z=-27, -4, and -22; $T=3.61$; $P_{fwe,scv}=.06$), right amygdala (Figure 5A; peak voxels: x, y, and z=30, -4, and -28; $T=3.27$; $P_{fwe,svc}=.09$), and right insula (Figure 5B; peak voxels: x, y, and z=33, -19, and 20; $T=4.61$; $P_{fwe,svc}=.09$) activity was observed in patients with OCD than in healthy controls at trend level. Task-related activity in the ROIs OFC, ACC, and right putamen was not significantly increased in patients with OCD compared to that in healthy controls. Finally, healthy controls showed no areas of increased BOLD response upon confrontation with OCD-related events or when performing virtual compulsive actions compared to patients with OCD.

Figure 4. Results of analysis of regions of interest. Trend significant cluster of hyperactivation in the left amygdala in patients with obsessive-compulsive disorder (OCD) compared with healthy controls during confrontation with OCD-related events. Montreal Neurological Institute coordinate: y=-4.

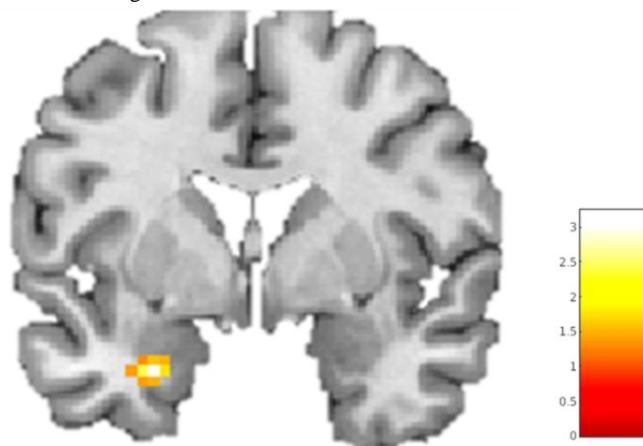
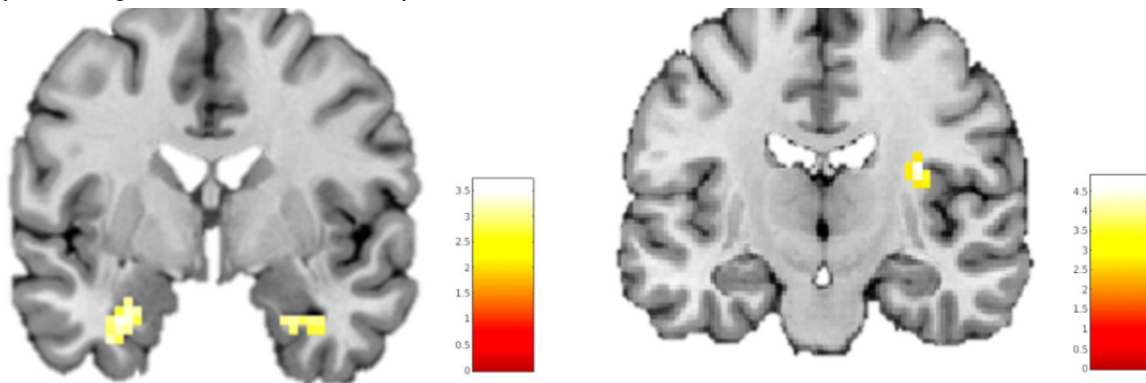


Figure 5. Results of analysis of regions of interest. Trend significant clusters of hyperactivation in patients with obsessive-compulsive disorder compared with healthy controls during performance of virtual compulsive actions, in the left and right amygdala (A; Montreal Neurological Institute [MNI] coordinate: $y=-4$) and right insula (B; MNI coordinate: $y=-19$).



Correlation Between Y-BOCS Scores and Brain Activation

Based on the aforementioned results, we focused on the correlation between amygdala and insula activation and Y-BOCS scores in patients with OCD. Upon confrontation with OCD-related items, there was no significant correlation between left amygdala activation and the Y-BOCS score ($r_s=-0.542$, $P=.13$). When performing virtual compulsive actions, there were no significant correlations between left amygdala ($r_s=-0.192$, $P=.65$) or right amygdala ($r_s=-0.419$, $P=.30$) and right insula ($r_s=-0.467$, $P=.24$) activation and Y-BOCS scores.

Discussion

Principal Findings

In this study, we performed an fMRI scanning session during a VR game for OCD, allowing us to examine brain regions upon confrontation with virtual symptom-provoking events and compulsions. We replicated findings from our previous study, showing that this VR game provoked more anxiety and virtual compulsive actions in patients with OCD than in healthy controls [6]. In the patient group, we also found a decrease in negative emotions following compulsive actions. Our results confirm that the VR game can provoke anxiety and virtual compulsions, which modulate negative emotions. We found no significant differences in brain activation between patients with OCD and healthy controls. The results show increased activity in the bilateral amygdala and the right insula at the trend level. We found an increase in left amygdala activity upon confrontation and an increase in bilateral amygdala and right insula activity with compulsive actions in patients with OCD. Contrary to our hypothesis, we did not find differences in brain activity in the OFC, ACC, and right putamen.

Comparison to Prior Work

The increase in left amygdala activity in response to confrontation is in line with previous symptom provocation studies [9]. The amygdala is involved in the detection of salient events and the mediation of negative emotions such as fear and anxiety [25,26]. The activity is associated with increased attention toward events and provoked feelings of anxiety. The laterality of the amygdala's response may be explained by fear

modulation of the left amygdala in response to learned, subject-dependent, aversive stimuli, in contrast to fear modulation by the right amygdala in generally aversive stimuli [27]. Increased bilateral amygdala and right insula activity during virtual compulsive actions is in line with previous provocation studies [9]. In our study, we observed brain activity while participants actually performed virtual compulsions. This is unique, since other studies use pictures, emotional faces, or written words to provoke symptoms. Our approach is a good example of an ecologically valid experiment that shows engagement of the amygdala and insula.

Thorsen et al [9] found pronounced right insula activation in studies with comorbid anxiety or mood disorders. In another study, the right insula was activated in response to disgust-inducing pictures in patients with contamination fear [28]. Indeed, the insula is suggested to play a role in processing disgust, and, in particular, the contamination/washing dimension of OCD is associated with higher disgust sensitivity [29]. Furthermore, Luigjes et al [30] found increased insula activation during risk processing in risk-averse patients with OCD, mainly in those with the doubt/checking dimension of OCD. The disgust and high risk-related virtual compulsions in our VR game (eg, washing hands after touching a dirty toilet or turning off a running flat iron) could have contributed to right insula activation.

In contrast to former studies, we did not find a difference in activity in the OFC or ACC. Most neuroimaging symptom provocation studies found increased activity in the OFC and ACC [9,11]. In one study, hypoactivation of the left ACC was observed in response to a handshake from a dirty virtual avatar in patients with OCD [31]. Furthermore, we did not find a correlation between the degree of brain activation and severity of symptoms. These results are nevertheless consistent with those of the meta-analysis of Thorsen et al [9]; the latter did not find a correlation between amygdala or insula activity and symptom severity.

Limitations

Our study has a few limitations. First, since this is a proof-of-concept study, we decided to recruit a small sample of 9 patients with OCD and 9 healthy controls, leading to limited statistical power. This impedes drawing definite conclusions regarding the ability of the VR game to activate the OCD-related

neural regions in patients compared to healthy controls. This could also explain why only trend-level activation patterns were observed in the amygdala and insula.

Second, in our group of patients with OCD, 5 patients used a SSRI or SNRI and 4 experienced a comorbid anxiety or mood disorder. Thorsen et al [9] found a negative correlation between SSRI use and right amygdala activation, and more pronounced right amygdala and less pronounced left amygdala activation in studies with more comorbid anxiety and mood disorders. Hence, in our results, both medication use and comorbid disorders could have affected left and right amygdala activation. Third, we used the “neutral” scenes (eg, the camera turning toward a wall) as contrast in the analyses during the game, and we cannot exclude the premise that participants already anticipated new events during the neutral scenes. If anything, this would have led to less pronounced activation patterns in the OCD-related brain regions in response to OCD-related events than to neutral events. Finally, 4 out of 9 patients with OCD indicated that their specific obsessions and compulsions were not triggered by the VR game. This indicates that the VR game, despite its comprehensive design, is not able to trigger OCD in all patients, possibly because the VR game did not represent all OCD dimensions. Indeed, studies have found distinct patterns of brain activation with OCD dimension-specific picture sets [32] or fully individualized picture sets [8].

Conclusions

In this proof-of-concept study, the VR game activated the bilateral amygdala and right insula at the trend level in patients with OCD, especially when performing virtual compulsions. Since this was a proof-of-principle study with 9 patients, it is

important to replicate these results in studies with a larger sample size. Our results suggest that immersive symptom provocation, with the possibility to conduct virtual compulsive actions, may allow us to study brain regions in patients with OCD in a more ecologically valid context, and, as such, can be seen as a stepping stone toward more research in this area. In particular, the possibility to observe brain activation when performing virtual compulsive actions might teach us more about the involved brain regions in this complex process that has proved difficult to study in an MRI scanner. So far, the VR game was not able to activate the whole OCD circuit including the OFC and ACC, possibly due to limited power because of the small sample size.

To our knowledge, this is the first study among patients with OCD using an innovative and interactive VR game entailing multiple OCD dimensions for symptom provocation inside a MRI scanner. New possibilities arise, for example, with the development of MRI-suitable head-mounted displays, to gain even higher levels of presence and immersion inside the MRI scanner. Furthermore, new VR technology allows for personalization of the virtual environment to the OCD dimension, which may improve power to detect brain regions [8]. Further research with larger sample sizes is needed to determine whether using a virtual environment on a head-mounted display that can be adjusted to OCD subtypes will lead to increased activation of neural regions related to OCD. If activation of OCD-related neural regions can be achieved during confrontations with events and while performing compulsive actions in a VR environment, this suggests the feasibility of exploring the neural basis of near-real-life OCD symptoms. This approach could yield deeper insights into the complex pathological foundations of OCD.

Acknowledgments

The authors wish to thank Monja Hoven for her assistance with MRI data analysis. No ChatGPT-generated text was used in this manuscript. WB is supported by the Dutch Research Council (NWO/ZonMW Vidi grant, 917-15-318). JL is supported by the NWO (NWO VENI fellowship grant 916-18-119).

Data Availability

The data sets generated or analyzed during this study are available from the corresponding author on reasonable request.

Authors' Contributions

MJvB drafted the manuscript, led the investigation and formal analysis, and supported the conceptualization of the study. GvW and WBB supported the formal analysis and reviewed and edited the manuscript. JL led the development of the study methodology, supervised the study, and reviewed and edited the manuscript. DD conceptualized and supervised the study, and reviewed and edited the manuscript.

Conflicts of Interest

GvW received research funding from Biogen, Bitbrain, and Philips for unrelated work. The other authors declare they have no conflicts of interest.

References

1. Denys D. Philos Ethics Humanit Med 2011 Feb 01;6:3 [FREE Full text] [doi: [10.1186/1747-5341-6-3](https://doi.org/10.1186/1747-5341-6-3)] [Medline: [21284843](https://pubmed.ncbi.nlm.nih.gov/21284843/)]
2. Ruscio AM, Stein DJ, Chiu WT, Kessler RC. The epidemiology of obsessive-compulsive disorder in the National Comorbidity Survey Replication. Mol Psychiatry 2010 Jan;15(1):53-63 [FREE Full text] [doi: [10.1038/mp.2008.94](https://doi.org/10.1038/mp.2008.94)] [Medline: [18725912](https://pubmed.ncbi.nlm.nih.gov/18725912/)]

3. Avila M, Conley R, Carpenter W. A comparison of symptom provocation procedures in psychiatry and other areas of medicine: implications for their ethical use in research. *Biol Psychiatry* 2001 Oct 01;50(7):479-486. [doi: [10.1016/s0006-3223\(01\)01221-5](https://doi.org/10.1016/s0006-3223(01)01221-5)] [Medline: [11600100](#)]
4. Laforest M, Bouchard S, Crétu A, Mesly O. Inducing an anxiety response using a contaminated virtual environment: validation of a therapeutic tool for obsessive-compulsive disorder. *Front ICT* 2016 Sep 05;3:18. [doi: [10.3389/fict.2016.00018](https://doi.org/10.3389/fict.2016.00018)]
5. Dehghan B, Saeidimehr S, Sayyah M, Rahim F. The effect of virtual reality on emotional response and symptoms provocation in patients with OCD: a systematic review and meta-analysis. *Front Psychiatry* 2021;12:733584 [FREE Full text] [doi: [10.3389/fpsy.2021.733584](https://doi.org/10.3389/fpsy.2021.733584)] [Medline: [35177996](#)]
6. van Bennekom MJ, de Koning PP, Gevonden MJ, Kasanmoentalib MS, Denys D. A virtual reality game to assess OCD symptoms. *Front Psychiatry* 2021 Jan 22;11:550165 [FREE Full text] [doi: [10.3389/fpsy.2020.550165](https://doi.org/10.3389/fpsy.2020.550165)] [Medline: [33551856](#)]
7. van Bennekom MJ, Kasanmoentalib MS, de Koning PP, Denys D. A virtual reality game to assess obsessive-compulsive disorder. *Cyberpsychol Behav Soc Netw* 2017 Nov;20(11):718-722. [doi: [10.1089/cyber.2017.0107](https://doi.org/10.1089/cyber.2017.0107)] [Medline: [29125791](#)]
8. Viol K, Aas B, Kastinger A, Kronbichler M, Schöller H, Reiter E, et al. Individual OCD-provoking stimuli activate disorder-related and self-related neuronal networks in fMRI. *Psychiatry Res Neuroimaging* 2019 Jan 30;283:135-144. [doi: [10.1016/j.psychres.2018.12.008](https://doi.org/10.1016/j.psychres.2018.12.008)] [Medline: [30594423](#)]
9. Thorsen A, Hagland P, Radua J, Mataix-Cols D, Kvale G, Hansen B, et al. Emotional processing in obsessive-compulsive disorder: a systematic review and meta-analysis of 25 functional neuroimaging studies. *Biol Psychiatry Cogn Neurosci Neuroimaging* 2018 Jun;3(6):563-571 [FREE Full text] [doi: [10.1016/j.bpsc.2018.01.009](https://doi.org/10.1016/j.bpsc.2018.01.009)] [Medline: [29550459](#)]
10. Nakao T, Nakagawa A, Yoshiura T, Nakatani E, Nabeyama M, Yoshizato C, et al. Brain activation of patients with obsessive-compulsive disorder during neuropsychological and symptom provocation tasks before and after symptom improvement: a functional magnetic resonance imaging study. *Biol Psychiatry* 2005 Apr 15;57(8):901-910. [doi: [10.1016/j.biopsych.2004.12.039](https://doi.org/10.1016/j.biopsych.2004.12.039)] [Medline: [15820711](#)]
11. Rotge J, Guehl D, Dilharreguy B, Cuny E, Tignol J, Bioulac B, et al. Provocation of obsessive-compulsive symptoms: a quantitative voxel-based meta-analysis of functional neuroimaging studies. *J Psychiatry Neurosci* 2008 Sep;33(5):405-412 [FREE Full text] [Medline: [18787662](#)]
12. Brooks H, Kichuk SA, Adams TG, Koller WN, Eken HN, Rance M, et al. Developing image sets for inducing obsessive-compulsive checking symptoms. *Psychiatry Res* 2018 Jul;265:249-255 [FREE Full text] [doi: [10.1016/j.psychres.2018.04.035](https://doi.org/10.1016/j.psychres.2018.04.035)] [Medline: [29763844](#)]
13. OCD net. URL: <https://www.ocdnet.nl> [accessed 2024-01-03]
14. Mumford JA. A power calculation guide for fMRI studies. *Soc Cogn Affect Neurosci* 2012 Aug 28;7(6):738-742 [FREE Full text] [doi: [10.1093/scan/nss059](https://doi.org/10.1093/scan/nss059)] [Medline: [22641837](#)]
15. Sheehan DV, Lecrubier Y, Sheehan KH, Amorim P, Janavs J, Weiller E, et al. The Mini-International Neuropsychiatric Interview (M.I.N.I.): the development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *J Clin Psychiatry* 1998;59 Suppl 20:22-33;quiz 34. [Medline: [9881538](#)]
16. Goodman WK, Price LH, Rasmussen SA, Mazure C, Fleischmann RL, Hill CL, et al. The Yale-Brown Obsessive Compulsive Scale. I. Development, use, and reliability. *Arch Gen Psychiatry* 1989 Nov 01;46(11):1006-1011. [doi: [10.1001/archpsyc.1989.01810110048007](https://doi.org/10.1001/archpsyc.1989.01810110048007)] [Medline: [2684084](#)]
17. Hamilton M. Hamilton Anxiety Rating Scale (HAM-A). *APA PsycNet* 1959:81-82. [doi: [10.1037/t02824-000](https://doi.org/10.1037/t02824-000)]
18. Hamilton M. A rating scale for depression. *J Neurol Neurosurg Psychiatry* 1960 Feb;23(1):56-62 [FREE Full text] [Medline: [14399272](#)]
19. igroup presence questionnaire (IPQ) overview. igroup.org. URL: <https://www.igroup.org/pq/ipq/index.php> [accessed 2023-12-27]
20. Poser B, Versluis M, Hoogduin J, Norris DG. BOLD contrast sensitivity enhancement and artifact reduction with multiecho EPI: parallel-acquired inhomogeneity-desensitized fMRI. *Magn Reson Med* 2006 Jun;55(6):1227-1235 [FREE Full text] [doi: [10.1002/mrm.20900](https://doi.org/10.1002/mrm.20900)] [Medline: [16680688](#)]
21. Wellcome Centre for Human Neuroimaging. URL: <http://www.fil.ion.ucl.ac.uk> [accessed 2023-12-27]
22. Tzourio-Mazoyer N, Landeau B, Papathanassiou D, Crivello F, Etard O, Delcroix N, et al. Automated anatomical labeling of activations in SPM using a macroscopic anatomical parcellation of the MNI MRI single-subject brain. *Neuroimage* 2002 Jan;15(1):273-289. [doi: [10.1006/nimg.2001.0978](https://doi.org/10.1006/nimg.2001.0978)] [Medline: [11771995](#)]
23. Maldjian JA, Laurienti PJ, Kraft RA, Burdette JH. An automated method for neuroanatomic and cytoarchitectonic atlas-based interrogation of fMRI data sets. *Neuroimage* 2003 Jul;19(3):1233-1239. [doi: [10.1016/s1053-8119\(03\)00169-1](https://doi.org/10.1016/s1053-8119(03)00169-1)] [Medline: [12880848](#)]
24. Brett M, Anton J, Valabregue R, Poline J. Region of interest analysis using an SPM toolbox. 2002 Presented at: 8th International Conference on Functional Mapping of the Human Brain,; June 2-6, 2002; Sendai, Japan.
25. Ressler K. Amygdala activity, fear, and anxiety: modulation by stress. *Biol Psychiatry* 2010 Jun 15;67(12):1117-1119 [FREE Full text] [doi: [10.1016/j.biopsych.2010.04.027](https://doi.org/10.1016/j.biopsych.2010.04.027)] [Medline: [20525501](#)]

26. van den Heuvel OA, van Wingen G, Soriano-Mas C, Alonso P, Chamberlain SR, Nakamae T, et al. Brain circuitry of compulsivity. *Eur Neuropsychopharmacol* 2016 May;26(5):810-827. [doi: [10.1016/j.euroneuro.2015.12.005](https://doi.org/10.1016/j.euroneuro.2015.12.005)] [Medline: [26711687](https://pubmed.ncbi.nlm.nih.gov/26711687/)]
27. Phelps EA, O'Connor KJ, Gatenby JC, Gore JC, Grillon C, Davis M. Activation of the left amygdala to a cognitive representation of fear. *Nat Neurosci* 2001 Apr;4(4):437-441. [doi: [10.1038/86110](https://doi.org/10.1038/86110)] [Medline: [11276236](https://pubmed.ncbi.nlm.nih.gov/11276236/)]
28. Shapira NA, Liu Y, He AG, Bradley MM, Lessig MC, James GA, et al. Brain activation by disgust-inducing pictures in obsessive-compulsive disorder. *Biol Psychiatry* 2003 Oct 01;54(7):751-756. [doi: [10.1016/s0006-3223\(03\)00003-9](https://doi.org/10.1016/s0006-3223(03)00003-9)] [Medline: [14512216](https://pubmed.ncbi.nlm.nih.gov/14512216/)]
29. Berle D, Phillips E. Disgust and obsessive-compulsive disorder: an update. *Psychiatry* 2006;69(3):228-238. [doi: [10.1521/psyc.2006.69.3.228](https://doi.org/10.1521/psyc.2006.69.3.228)] [Medline: [17040174](https://pubmed.ncbi.nlm.nih.gov/17040174/)]
30. Luigjes J, Figeo M, Tobler P, van den Brink W, de Kwaasteniet B, van Wingen G, et al. Doubt in the insula: risk processing in obsessive-compulsive disorder. *Front Hum Neurosci* 2016;10:283 [FREE Full text] [doi: [10.3389/fnhum.2016.00283](https://doi.org/10.3389/fnhum.2016.00283)] [Medline: [27378883](https://pubmed.ncbi.nlm.nih.gov/27378883/)]
31. Ku J, Kim SJ, Lee H, Jung K, An SK, Namkoong K, et al. Deactivation of anterior cingulate cortex during virtual social interaction in obsessive-compulsive disorder. *Psychiatry Res Neuroimaging* 2020 Oct 30;304:111154. [doi: [10.1016/j.psychresns.2020.111154](https://doi.org/10.1016/j.psychresns.2020.111154)] [Medline: [32763759](https://pubmed.ncbi.nlm.nih.gov/32763759/)]
32. Mataix-Cols D, Wooderson S, Lawrence N, Brammer MJ, Speckens A, Phillips ML. Distinct neural correlates of washing, checking, and hoarding symptom dimensions in obsessive-compulsive disorder. *Arch Gen Psychiatry* 2004 Jun 01;61(6):564-576. [doi: [10.1001/archpsyc.61.6.564](https://doi.org/10.1001/archpsyc.61.6.564)] [Medline: [15184236](https://pubmed.ncbi.nlm.nih.gov/15184236/)]

Abbreviations

ACC: anterior cingulate cortex

BOLD: blood oxygenation level-dependent

DSM-IV: Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition

fMRI: functional magnetic resonance imaging

MRI: magnetic resonance imaging

OCD: obsessive-compulsive disorder

OFC: orbitofrontal cortex

ROI: region of interest

SNRI: serotonin and norepinephrine reuptake inhibitor

SSRI: selective serotonin reuptake inhibitor

VAS: visual analog scale

VR: virtual reality

Y-BOCS: Yale-Brown Obsessive Compulsive Scale

Y-BOCS-SC: Yale-Brown Obsessive Compulsive Scale Symptom Checklist

Edited by T Leung; submitted 21.03.23; peer-reviewed by N Mungoli; comments to author 20.09.23; revised version received 19.12.23; accepted 26.12.23; published 19.01.24.

Please cite as:

van Bennekom MJ, van Wingen G, Bruin WB, Luigjes J, Denys D

Brain Activation During Virtual Reality Symptom Provocation in Obsessive-Compulsive Disorder: Proof-of-Concept Study

JMIR XR Spatial Comput 2024;1:e47468

URL: <https://xr.jmir.org/2024/1/e47468>

doi: [10.2196/47468](https://doi.org/10.2196/47468)

PMID:

©Martine J van Bennekom, Guido van Wingen, Willem Benjamin Bruin, Judy Luigjes, Damiaan Denys. Originally published in *JMIR XR and Spatial Computing* (<https://xr.jmir.org>), 19.01.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in the *Journal of Medical Internet Research*, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org>, as well as this copyright and license information must be included.

Original Paper

Virtual Reality for Basic Life Support Training in High School Students: Thematic Analysis of Focus Group Interviews

Hyojin Jennifer Min¹, MSN, PhD; Caroline Andler¹, MD; Rebecca Ortiz La Banca Barber¹, MSN, PhD; Todd P Chang¹, MD; Cristian Abelairas-Gomez², PhD; Laquanda T Knowlin¹, MD; Deborah R Liu¹, MD; Nino Fijačko³, MSc

¹Children's Hospital of Los Angeles, Los Angeles, CA, United States

²Faculty of Education Sciences, Universidade de Santiago de Compostela, Santiago de Compostela, Spain

³Faculty of Health Sciences, University of Maribor, Maribor, Slovenia

Corresponding Author:

Hyojin Jennifer Min, MSN, PhD

Children's Hospital of Los Angeles

4650 Sunset Blvd

Los Angeles, CA, 90027

United States

Phone: 1 3233614606

Email: hmin@chla.usc.edu

Abstract

Background: High-quality and engaging cardiopulmonary resuscitation (CPR) training of both health care professionals and members of the public is necessary to provide timely and effective CPR to maximize survival and minimize injuries. Virtual reality (VR) is a novel method to enhance CPR engagement and training. However, a near-peer mentoring framework has not been applied in such training to date.

Objective: The purpose of this pilot qualitative study was to understand the acceptability and feasibility of using VR technology to introduce basic life support (BLS) to high school students reinforced by near-peer coaching.

Methods: Dyads of high school students underwent BLS training in CPR using a VR experience reinforced by the near-peer mentoring model. Focus group interviews were performed following the intervention. The interview sessions were recorded, transcribed verbatim, and subjected to thematic analysis. VR software data were analyzed after five cycles of chest compressions between the two participants.

Results: The overwhelming responses from the three dyads of high school students indicated positive acceptance of learning CPR using VR. Analysis of emerging themes revealed three main categories of barriers and facilitators: (1) motivation to learn CPR, (2) CPR learning modality, and (3) coaching CPR content. These themes supported the theoretical framework of an "intention-focused" paradigm leading to acquiring the skills needed to perform CPR and ultimately increasing the chances of a bystander performing CPR.

Conclusions: This study highlights the potential for training a unique population to increase bystander effects using novel VR technology coupled with a near-peer mentoring method. Further research is warranted to measure the outcome of the knowledge attained and the intention to perform CPR by high school students who participate in CPR education using VR and a near-peer mentoring method.

(*JMIR XR Spatial Comput* 2024;1:e53212) doi:[10.2196/53212](https://doi.org/10.2196/53212)

KEYWORDS

virtual reality; mixed reality; technology; basic life support; cardiovascular pulmonary resuscitation; near-peer mentoring; education; high school students

Introduction

Sudden cardiac arrest (SCA) is an uncommon phenomenon in youth; however, according to the Centers for Disease Control

and Prevention, approximately 2000 healthy people under 25 years of age in the United States die each year due to SCA [1]. Regardless of one's age, the survival odds of SCA outside of a hospital setting are low, which is likely related to the low

bystander cardiopulmonary resuscitation (CPR) rates [2,3]. Therefore, it is important to increase the general public's awareness and knowledge levels of CPR to consequently increase the number of bystanders who may initiate CPR in an emergency situation [4]. Educating and engaging adolescents in life-saving maneuvers such as CPR is a crucial step in increasing the lifelong ability and motivation to take actions in an emergency [5,6].

High-quality and engaging CPR training of both health care professionals and members of the public is necessary to provide timely and effective CPR to maximize survival and minimize injuries [7]. Traditionally, CPR training has occurred in an in-person group setting utilizing CPR mannequins. Due to the COVID-19 pandemic, this traditional approach of CPR training shifted toward a focus on smaller group sizes to minimize hands-on simulation activities. Virtual reality (VR) is a novel method to enhance CPR engagement and training, which has shown rapid growth since 2019 [8,9]. The immersive VR training induces a greater sense of presence and agency when compared to traditional CPR training, and may be more effective in increasing the intention and initiative to perform CPR in real-world emergencies [10]. Such VR technology enhancements have been particularly well received by the "technology natives" of the younger generation [11]. A systematic review identified the current gap of this field as the lack of educational programs rated at 3-4 on the Kirkpatrick model, which is a method of evaluating the results of training and learning programs [12]. This highlights the importance of continued development and improvement in simulation education, particularly in the context of CPR training. While there is a growing interest in leveraging novel technologies for CPR training, few studies have assessed their potential [13].

Near-peer mentoring is a learner-centered model, where the pairing of mentors and mentees close in age and developmental stage allows for mentors to draw on personal experiences to connect with mentees. This facilitates connections and reflections integral to the experiential learning process [14]. However, the relationship between CPR training and use of VR technology based on a near-peer mentoring framework has not yet been investigated, particularly in the high school population.

To fill this gap, our primary objective was to assess the feasibility of VR technology as a novel learning modality for CPR training and to apply the near-peer mentoring model in this CPR training among adolescents. Toward this end, we evaluated the relationship between the following three domains: CPR, VR, and near-peer mentoring. Our secondary objective was to collect and document the lived experiences of adolescents upon experiencing VR to obtain basic skill sets associated with CPR.

Methods

Recruitment

High school students were recruited from participants of Camp Children's Hospital Los Angeles (CHLA), which is an annual,

week-long health care career exploration summer camp for high school students between 15 to 17 years of age in Los Angeles County. The VR-based CPR sessions were offered as a voluntary option. The study was conducted in the Las Madrinas Simulation Center at CHLA.

The target number of participants to recruit for this qualitative pilot study was not established a priori. According to Creswell [15], between 5 and 25 interviews for phenomenological studies were reported to be appropriate. In addition, Morse [16] specified recruiting at least 6 participants for phenomenological studies. Neither of these studies included the rationale for the indicated numbers.

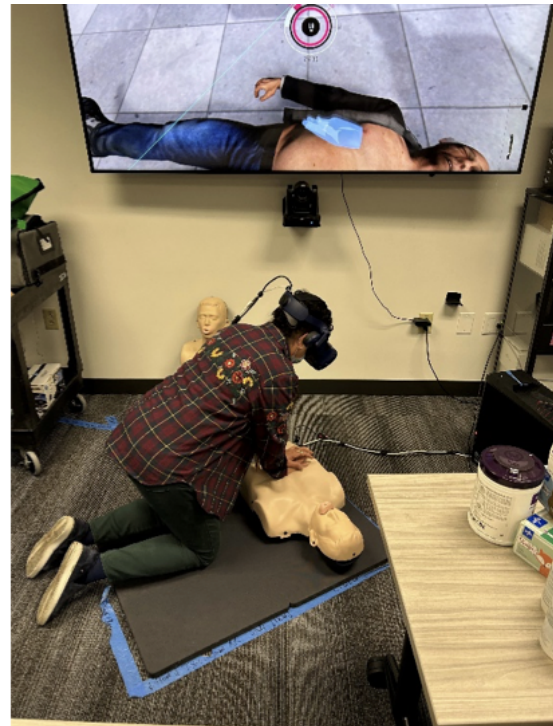
Ethical Considerations

The protocol and participant-facing materials underwent review by the CHLA institutional review board, and approval was obtained prior to any data collection (case number CHLA-22-00230). Informed consent and assent were obtained from the identified participants and their respective parents prior to the day of the study. Participants were not offered compensation. Consents and assents were electronically obtained via the Research Electronic Data Capture (REDCap) system where corresponding participant IDs were created. The identifiers were removed during the transcription process and the recordings were destroyed once transcription was completed.

Data Collection

Dyads of high school students underwent CPR training using a VR-based hybrid simulation platform (CBS, TetraSignum). Prior to the VR session, each dyad watched approximately 30 minutes of didactic content delivered by a virtual avatar instructor. Following the didactic portion, the students took turns and had an opportunity to perform hands-on CPR on a quality CPR (QCPR) mannequin. Next, the VR software data, which scored five cycles of chest compressions between the two participants, were analyzed. We used a Vive Pro (HTC) hardware system, which enabled simulcasting the VR user's view to a screen for others to watch. The VR software superimposes a virtual avatar over the location of the mannequin to simulate a human in cardiac arrest. This QCPR technology uses wireless sensors embedded in the mannequin to measure the effectiveness of core CPR components [17]. The steps of the CPR consisted of (1) a check response, (2) a call for help, (3) a check for breathing, (4) five cycles of chest compressions and rescue breaths, and (5) using an automated external defibrillator. This experience was reinforced by the near-peer mentoring model as a pair (Figure 1). The sessions were immediately followed by approximately 45 minutes of focus group interviews led by the research team. The debrief interview sessions used open-ended questions addressing the domains of interest and the participants' lived experiences. The interview sessions were recorded, transcribed verbatim, and analyzed.

Figure 1. Dyads of campers underwent basic life support training using a virtual reality–based hybrid simulation platform.



Phenomenology

Phenomenology is a type of a qualitative research method with roots in psychology and philosophy. Phenomenology is best applied to understand the lived experiences of individuals where the focus is exploring [18,19]. In our study, participants interested in a career in health care intentionally chose the VR CPR tract as part of their day. Accordingly, this study aimed to gain insight as to “how individuals make sense of the world to provide insightful accounts of their subjective experience” [18], and to gain understanding of the phenomenon of introducing the contents of basic life support (BLS) and CPR using VR and near-peer mentoring to high school students.

Data Analysis

The interview sessions were recorded and transcribed verbatim. An interdisciplinary team of medical researchers used a thematic analysis approach as described by Braun and Clarke [20]. The first three authors (HJM, CA, and ROLBB) read the transcripts to understand the students’ perceptions and acceptability of using VR to learn CPR with a near-peer mentoring model. Next, the transcripts were coded systematically across the three team members and combined for reflexive thematic analysis [21]. The three research team members, including two research nurses (HJM and ROLBB) and a physician (CA), analyzed the focus group data using constant-comparison analysis. This approach allows for richer interpretations of meaning, particularly across multidisciplinary research members. Constant comparison also allowed for refining, defining, and naming themes. Once codes were created, they were grouped into barriers and facilitators, and then broader themes were identified by circling back to the near-peer mentoring model and the intersection between VR

and CPR. Finally, the thematic auditors (DRL and TPC) reviewed the identified themes for any discrepancies.

Results

Recruitment

This pilot study launched over the summer of 2022. We recruited a total of three dyads of 6 high school students from a total of 31 students participating in the CHLA camp. The parents of the 6 participants provided consent and individual participants provided assent to be interviewed to share their lived experiences of learning CPR using VR and acting in the role of “coach” based on the near-peer mentoring model. The cohort comprised 2 boys and 4 girls with a mean age of 16.5 (range 15-17) years. Of note, this was the first on-site camp since the COVID-19 pandemic; therefore, there was a smaller total group of campers selected for that year, ultimately leading to a smaller sample size for this study.

Data Saturation

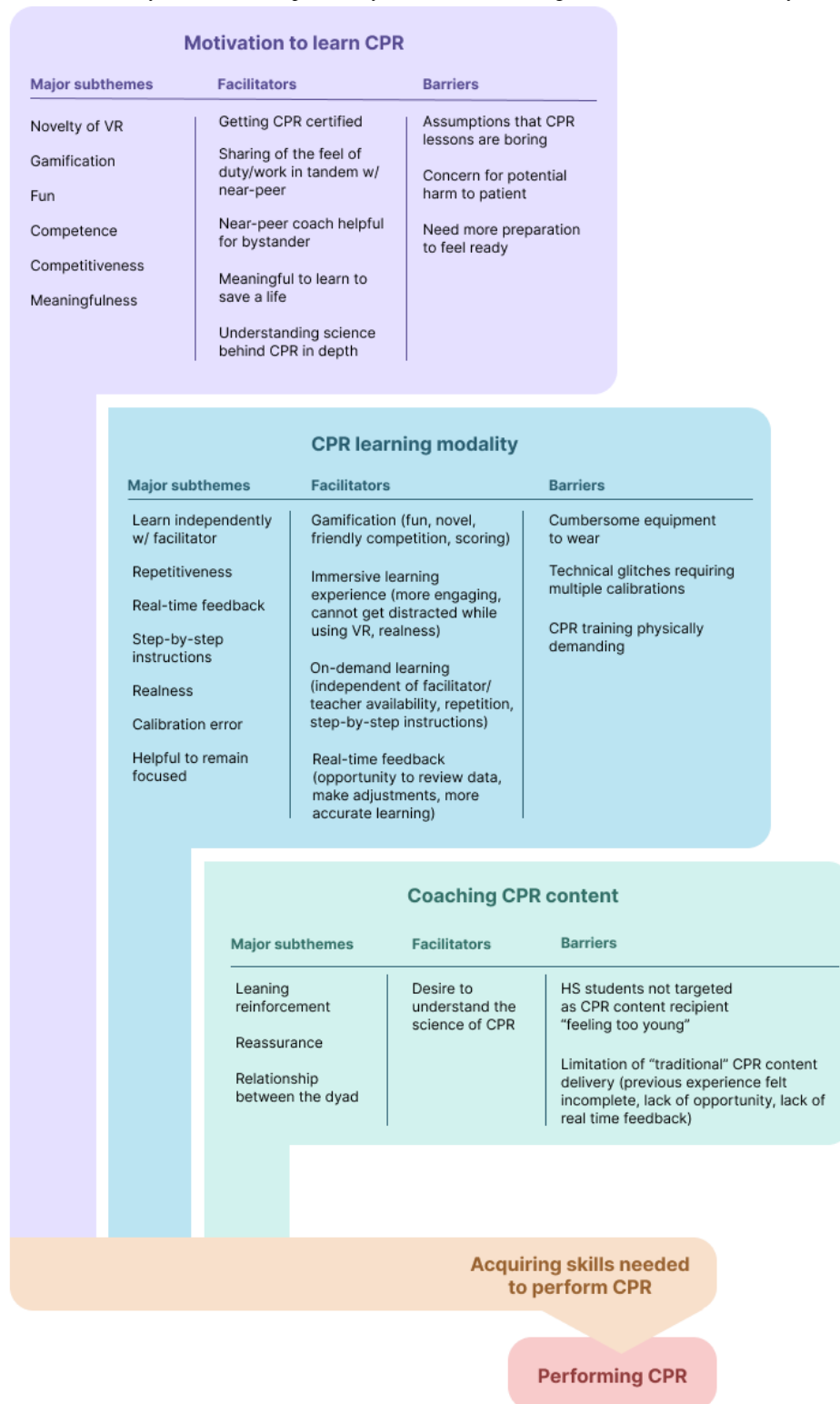
Data saturation in a qualitative study is defined as the collection of qualitative data to a point of “sense of closure,” because there are no new insights obtained and the data yield redundant information [19,22]. Attempts were made to have the campers return to campus after the camp had been completed; however, since the students were back at school, we were unable to recruit additional participants.

Themes

Main Themes Identified

During the qualitative analysis process, three themes were identified: (1) motivation to learn CPR, (2) CPR learning modality, and (3) coaching CPR content (Figure 2).

Figure 2. Summary of the thematic analysis. CPR: cardiopulmonary resuscitation; HS: high school; VR: virtual reality; w/: with.



Motivation to Learn CPR

Motivation to learn CPR was defined by themes arising from the individuals’ expressed extrinsic and intrinsic motivation to learn. Participants reported the novelty of VR and the engaging space of the simulation center to be a motivating factor in learning CPR. Our method of learning was unique when compared to the traditional method of a CPR class and its preconceived notions because it created “a more engaging space

for kids to be more interested in CPR.” Furthermore, the gamification of learning by VR was considered to be fun, and even peers who may not have an interest in health care would also be interested since VR would “automatically assumed to be fun because it’s a game.” The final scores provided by the software served as positive feedback of competence and elicited competitiveness as a source of encouragement in the participants’ ability to achieve success. Lastly, many of the

participants reported that it was meaningful to be able to learn how to save a life.

CPR Learning Modality

The learning modality of CPR was defined by themes arising from the method, medium, or delivery of the CPR learning via VR and peer coaching. The participants reported that being able to learn independently without having a facilitator or teacher supervision would allow them to repeat the learning process at their own pace (eg, “you keep practicing, eventually it’ll become second nature”) and that when faced with an emergency, one would feel more prepared to assist. The real-time feedback from the avatar trainer and the in-person peer coach was considered to be helpful. In addition, the ability to address concerns such as “Are we going at the right pace?” “Are we going too slow?” “Is the pressure right?” on a real-time basis enabled immediately making changes and adjustments in real time as needed. The step-by-step instructions helped to reinforce the knowledge. One camper shared, “I like that it went step by step because it helped to absorb the information easier.” There was also feedback regarding the avatar often moving out of sync with little or no time for the participant to reflect. For instance, “it was like after you finish check response and then he just quickly moved on to the next one. Maybe just a little bit time to reflect...” Lastly, the realness of the VR simulation and tactile hands-on learning modality helped participants to be better prepared when compared to the traditional lecture-based or passive online modules: “I liked it was more accurate. I like that it put me in a real-life situation and, I felt like it made me more prepared.” The participants also shared calibration error to be a source of distraction in learning, which occurred when the mannequin’s sensor and the participant’s hands were not calibrated correctly. Lastly, use of VR enabled the participants to remain focused while learning, because “you weren’t looking around or getting distracted by anything,” since while the headset is on, the participant is engaged in the “VR world” and is therefore unable to become distracted.

Coaching CPR Content

Coaching CPR content was defined by themes arising from the dyads’ experiences of serving as a coach and being coached as a pair. Although the pair started by watching the 30-minute introduction training videos together, many participants shared that being able to coach after having the opportunity to go through the program first helped them to feel more confident in coaching. The comments offered as a coach served as additional learning reinforcement, as stated by one participant: “whatever I said to her stuck in my mind, so I was able to remember that for when I went.” The presence of the coach also provided a sense of reassurance because participants “felt reassured like I wasn’t being pressured to do everything and then forgetting anything.” Working in tandem in CPR training impacted the pair’s perception of the responsibility of a “scary situation” to be less daunting. An important factor to be mindful in assigning of the pair was assessment of the relationship between the dyad:

If I had just met someone, maybe I wouldn’t be as comfortable telling them what to do or what not.

Probably just the relationship with people would be the biggest aspect of coaching.

Recommendations for Future Projects Provided by Participants

Helpful ideas for future iterations of the VR-based CPR trainings included adding options of different major metropolitan cities, background music, and personalization of avatars. Moreover, participants suggested expanding the trainings to include a pediatric population, ranging from infants to toddlers to school-aged children. Lastly, they suggested using a more seamless VR technology to impose less of a burden associated with the headset.

Discussion

Our findings show that it will be valuable to leverage the currently available VR technology to promote CPR education for high school students. Moreover, purposeful inclusion of a near-peer mentoring approach can have a synergistic contribution to the training and result in a positive learning experience. The themes identified in our study build upon the existing theoretical framework proposed by Panchal et al [23], termed the “intention-focused model for bystander CPR performance,” which allows gaining an understanding of the determinants of bystanders’ decision-making process. The proximal domains preceding the intentions start with the bystander’s demographic characteristics, including gender, age, personality traits, and education level. These baseline demographic variables then lead to their “beliefs,” categorized by “attitudes,” “perceived norms,” and “self-efficacy,” in performing CPR. These beliefs then result in the “intention” to perform CPR, bolstered by the “skills needed to perform CPR” as a determinant of behavior, which ultimately leads to the action of performing CPR.

Therefore, the themes unveiled from our qualitative data analysis were consistent with the intention-focused model for the bystander CPR performance framework. Our research design of phenomenology and documentation of the “lived experiences” of the participants expanded upon the demographic characteristics and beliefs associated with CPR prior to this new learning experience. The main purpose of this VR CPR project was to equip the participants with the knowledge and skills needed to perform CPR. The three major themes unveiled from our analysis add to the preceding themes leading up to the “skills needed to perform CPR” in the intention-focused model, which were (1) motivation to learn CPR, (2) CPR learning modality, and (3) coaching CPR content.

The motivation to learn CPR is a new domain that is distinct from the previously identified “attitudes,” “perceived norms,” and “self-efficacy” about performing CPR. Self-determination theory is a motivational theory of personality, development, and social process that examines how individuals are driven and depicts motivation on a continuum [24]. Notably, our participants were highly motivated individuals who are interested in future careers in health care. In accordance with the framework of Panchal et al [23], it will be important to introduce a moderating factor to motivate high school students

to be intrinsically motivated where the motivation's root stems from interest, enjoyment, and satisfaction.

The overwhelming positive feedback received by the participants in regard to learning CPR via VR is consistent with prior research showing a link between novelty and curiosity [11,25,26], where “when a novel stimulus affects an organism's [brain] receptors, there will occur a driving stimulus producing response called curiosity” [26]. Our novel approach to the learning and delivery of CPR content may have steered the “attitudes” and “perceived norms” about performing CPR in a positive direction. A scientific statement by the American Heart Association noted that novel methodologies and digital platforms (ie, gamified learning, social media, and crowdsourcing) do not necessarily improve response and performance; however, novelty allows for the potential to reach a larger population with various types of learners [27]. Likewise, although this pilot study did not measure the changes in the “intention to perform CPR,” based on the feedback provided by participants, this approach has the potential to reach and create interest in high school students.

Since the VR CPR learning modality would allow for learners to repeat the learning sequences independently in their own time, as one participant stated, “if anything like this were to happen, you would be able to do it.” A similar study from 2016 that evaluated multiplayer virtual training in medicine among 12 Swedish medical students found that virtual training may result in “erroneous self-beliefs” affecting future clinical practices [11]. This study points to the importance of future studies to measure the “intention to perform CPR” and assessment of the efficacy of VR-based training compared to traditional training methods [13].

There was a similar study evaluating the influence of near-peer mentoring in CPR workshops on medical students' knowledge and satisfaction [28]. Similar to the findings with our high school students, the previous study reported the benefits of this type of mentorship to be helpful in that the peers have similar levels of experience, and they are more familiar with the educational needs and better understand the learning process and potential areas for confusion [28].

The selection of inherently motivated high school students with career aspirations in health care may have posed a bias, thereby limiting the generalizability of the study, in addition to the small sample size of 6 participants. In addition, consistent with the design of this pilot study, it can be difficult to present generalizable findings of phenomenological research due to the highly individual records of lived experiences. Lastly, although we did not collect measures specifically evaluating changes in intentions to perform CPR in the future, previous studies have indicated that a bystander who had experienced CPR training was up to 6 times more likely to perform CPR when witnessing an out-of-hospital cardiac arrest [3,29,30]. Although outside of the scope and aims of this study, we did not collect any data to measure the quality of the CPR. Nevertheless, it is still meaningful that the students were trained on the sequences of BLS.

Our findings show that it is feasible to leverage a novel technology such as VR to enhance the CPR learning experience. Particularly for high school students, learning CPR using VR served as a source of motivation, which was fostered by the unique modality of learning in the presence of a near-peer coach. These benefits could contribute toward training a future generation who will be more confident to perform CPR as a bystander in an emergency situation.

Acknowledgments

We are grateful to the Las Madrinas Simulation Center and Institute for Nursing and Interprofessional Research at the Children's Hospital of Los Angeles.

Data Availability

Data for this study, which comprise the transcription files and coding from the first 3 authors, may be made available upon request to the corresponding author.

Conflicts of Interest

None declared.

References

1. Ackerman M, Atkins DL, Triedman JK. Sudden cardiac death in the young. *Circulation* 2016 Mar 08;133(10):1006-1026 [FREE Full text] [doi: [10.1161/CIRCULATIONAHA.115.020254](https://doi.org/10.1161/CIRCULATIONAHA.115.020254)] [Medline: [26951821](https://pubmed.ncbi.nlm.nih.gov/26951821/)]
2. Eckstein M, Stratton SJ, Chan LS. Cardiac Arrest Resuscitation Evaluation in Los Angeles: CARE-LA. *Ann Emerg Med* 2005 May;45(5):504-509. [doi: [10.1016/j.annemergmed.2004.11.024](https://doi.org/10.1016/j.annemergmed.2004.11.024)] [Medline: [15855947](https://pubmed.ncbi.nlm.nih.gov/15855947/)]
3. Swor R, Khan I, Domeier R, Honeycutt L, Chu K, Compton S. CPR training and CPR performance: do CPR-trained bystanders perform CPR? *Acad Emergency Med* 2006 Jun;13(6):596-601. [doi: [10.1111/j.1553-2712.2006.tb01017.x](https://doi.org/10.1111/j.1553-2712.2006.tb01017.x)]
4. Özbilgin Ş, Akan M, Hancı V, Aygün C, Kuvaki B. Evaluation of public awareness, knowledge and attitudes about cardiopulmonary resuscitation: report of İzmir. *Turk J Anaesthesiol Reanim* 2015 Dec;43(6):396-405 [FREE Full text] [doi: [10.5152/TJAR.2015.61587](https://doi.org/10.5152/TJAR.2015.61587)] [Medline: [27366536](https://pubmed.ncbi.nlm.nih.gov/27366536/)]

5. Calicchia S, Cangiano G, Capanna S, De Rosa M, Papaleo B. Teaching life-saving manoeuvres in primary school. *Biomed Res Int* 2016;2016:2647235-2647236. [doi: [10.1155/2016/2647235](https://doi.org/10.1155/2016/2647235)] [Medline: [27957491](https://pubmed.ncbi.nlm.nih.gov/27957491/)]
6. Zenani NE, Bello B, Molekodi M, Useh U. Effectiveness of school-based CPR training among adolescents to enhance knowledge and skills in CPR: a systematic review. *Curationis* 2022 Nov 18;45(1):e1-e9 [FREE Full text] [doi: [10.4102/curationis.v45i1.2325](https://doi.org/10.4102/curationis.v45i1.2325)] [Medline: [36453813](https://pubmed.ncbi.nlm.nih.gov/36453813/)]
7. Lin S, Scales DC. Cardiopulmonary resuscitation quality and beyond: the need to improve real-time feedback and physiologic monitoring. *Crit Care* 2016 Jun 28;20(1):182 [FREE Full text] [doi: [10.1186/s13054-016-1371-9](https://doi.org/10.1186/s13054-016-1371-9)] [Medline: [27349642](https://pubmed.ncbi.nlm.nih.gov/27349642/)]
8. Kuyt K, Park S, Chang TP, Jung T, MacKinnon R. The use of virtual reality and augmented reality to enhance cardio-pulmonary resuscitation: a scoping review. *Adv Simul* 2021 Apr 12;6(1):11 [FREE Full text] [doi: [10.1186/s41077-021-00158-0](https://doi.org/10.1186/s41077-021-00158-0)] [Medline: [33845911](https://pubmed.ncbi.nlm.nih.gov/33845911/)]
9. Moore N, Yoo S, Poronnik P, Brown M, Ahmadpour N. Exploring user needs in the development of a virtual reality-based advanced life support training platform: exploratory usability study. *JMIR Serious Games* 2020 Aug 07;8(3):e20797 [FREE Full text] [doi: [10.2196/20797](https://doi.org/10.2196/20797)] [Medline: [32763877](https://pubmed.ncbi.nlm.nih.gov/32763877/)]
10. Liu W, Zeng N, Pope ZC, McDonough DJ, Gao Z. Acute effects of immersive virtual reality exercise on young adults' situational motivation. *J Clin Med* 2019 Nov 12;8(11):1947 [FREE Full text] [doi: [10.3390/jcm8111947](https://doi.org/10.3390/jcm8111947)] [Medline: [31726672](https://pubmed.ncbi.nlm.nih.gov/31726672/)]
11. Creutzfeldt J, Hedman L, Felländer-Tsai L. Cardiopulmonary resuscitation training by avatars: a qualitative study of medical students' experiences using a multiplayer virtual world. *JMIR Serious Games* 2016 Dec 16;4(2):e22 [FREE Full text] [doi: [10.2196/games.6448](https://doi.org/10.2196/games.6448)] [Medline: [27986645](https://pubmed.ncbi.nlm.nih.gov/27986645/)]
12. Johnston S, Coyer FM, Nash R. Kirkpatrick's evaluation of simulation and debriefing in health care education: a systematic review. *J Nurs Educ* 2018 Jul 01;57(7):393-398. [doi: [10.3928/01484834-20180618-03](https://doi.org/10.3928/01484834-20180618-03)] [Medline: [29958308](https://pubmed.ncbi.nlm.nih.gov/29958308/)]
13. Ricci S, Calandrino A, Borgonovo G, Chirico M, Casadio M. Viewpoint: Virtual and augmented reality in basic and advanced life support training. *JMIR Serious Games* 2022 Mar 23;10(1):e28595 [FREE Full text] [doi: [10.2196/28595](https://doi.org/10.2196/28595)] [Medline: [35319477](https://pubmed.ncbi.nlm.nih.gov/35319477/)]
14. Abeywardana SU, Velasco S, Hall N, Dillon J, Chun C. Near-peer mentoring in an undergraduate research training program at a large master's comprehensive institution: the Case of CSULB BUILD. *UI J* 2020;11(1):12477 [FREE Full text] [Medline: [35558987](https://pubmed.ncbi.nlm.nih.gov/35558987/)]
15. Creswell JW. *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. New York: Sage Publications; 1997.
16. Morse JM. Designing funded qualitative research. In: Denzin NK, Lincoln YS, editors. *Handbook of Qualitative Inquiry*. Thousand Oaks, CA: Sage Publications; 1994:220-235.
17. Labuschagne MJ, Arbee A, de Klerk C, de Vries E, de Waal T, Jhetam T, et al. A comparison of the effectiveness of QCPR and conventional CPR training in final-year medical students at a South African university. *Afr J Emerg Med* 2022 Jun;12(2):106-111 [FREE Full text] [doi: [10.1016/j.afjem.2022.02.001](https://doi.org/10.1016/j.afjem.2022.02.001)] [Medline: [35251921](https://pubmed.ncbi.nlm.nih.gov/35251921/)]
18. Korstjens I, Moser A. Series: Practical guidance to qualitative research. Part 2: Context, research questions and designs. *Eur J Gen Pract* 2017 Dec 29;23(1):274-279 [FREE Full text] [doi: [10.1080/13814788.2017.1375090](https://doi.org/10.1080/13814788.2017.1375090)] [Medline: [29185826](https://pubmed.ncbi.nlm.nih.gov/29185826/)]
19. Polit D, Beck C. *Nursing Research: Generating and Assessing Evidence for Nursing Practice*. Philadelphia: Lippincott Williams & Wilkins; 2008.
20. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol* 2006 Jan;3(2):77-101. [doi: [10.1191/1478088706qp063oa](https://doi.org/10.1191/1478088706qp063oa)]
21. Byrne D. A worked example of Braun and Clarke's approach to reflexive thematic analysis. *Qual Quant* 2021 Jun 26;56(3):1391-1412. [doi: [10.1007/s11135-021-01182-y](https://doi.org/10.1007/s11135-021-01182-y)]
22. Moser A, Korstjens I. Series: Practical guidance to qualitative research. Part 3: Sampling, data collection and analysis. *Eur J Gen Pract* 2018 Dec;24(1):9-18 [FREE Full text] [doi: [10.1080/13814788.2017.1375091](https://doi.org/10.1080/13814788.2017.1375091)] [Medline: [29199486](https://pubmed.ncbi.nlm.nih.gov/29199486/)]
23. Panchal AR, Fishman J, Camp-Rogers T, Starodub R, Merchant RM. An "Intention-Focused" paradigm for improving bystander CPR performance. *Resuscitation* 2015 Mar;88:48-51 [FREE Full text] [doi: [10.1016/j.resuscitation.2014.12.006](https://doi.org/10.1016/j.resuscitation.2014.12.006)] [Medline: [25534077](https://pubmed.ncbi.nlm.nih.gov/25534077/)]
24. Ryan RM, Deci EL. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am Psychol* 2000 Jan;55(1):68-78. [doi: [10.1037//0003-066x.55.1.68](https://doi.org/10.1037//0003-066x.55.1.68)] [Medline: [11392867](https://pubmed.ncbi.nlm.nih.gov/11392867/)]
25. Glanzer M. Curiosity, exploratory drive, and stimulus satiation. *Psychol Bull* 1958 Sep;55(5):302-315. [doi: [10.1037/h0044731](https://doi.org/10.1037/h0044731)] [Medline: [13591450](https://pubmed.ncbi.nlm.nih.gov/13591450/)]
26. Jackson C. Motivating participation through novelty cues. 2019. URL: <https://surface.syr.edu/cgi/viewcontent.cgi?article=2047&context=etd> [accessed 2024-03-27]
27. Cheng A, Nadkarni VM, Mancini MB, Hunt EA, Sinz EH, Merchant RM, American Heart Association Education Science Investigators; on behalf of the American Heart Association Education Science Programs Committee, Council on Cardiopulmonary, Critical Care, Perioperative Resuscitation; Council on Cardiovascular Stroke Nursing; Council on Quality of Care Outcomes Research. Resuscitation education science: educational strategies to improve outcomes from cardiac arrest: a scientific statement from the American Heart Association. *Circulation* 2018 Aug 07;138(6):e82-e122. [doi: [10.1161/CIR.0000000000000583](https://doi.org/10.1161/CIR.0000000000000583)] [Medline: [29930020](https://pubmed.ncbi.nlm.nih.gov/29930020/)]

28. Sabeghi H, Mogharab M, Farajzadeh Z, Aria Moghaddam E. Effects of near-peer CPR workshop on medical students' knowledge and satisfaction. *Res Dev Med Educ* 2021 Jun 07;10(1):9. [doi: [10.34172/rdme.2021.009](https://doi.org/10.34172/rdme.2021.009)]
29. Tanigawa K, Iwami T, Nishiyama C, Nonogi H, Kawamura T. Are trained individuals more likely to perform bystander CPR? An observational study. *Resuscitation* 2011 May;82(5):523-528. [doi: [10.1016/j.resuscitation.2011.01.027](https://doi.org/10.1016/j.resuscitation.2011.01.027)] [Medline: [21354688](https://pubmed.ncbi.nlm.nih.gov/21354688/)]
30. Matsuyama T, Scapigliati A, Pellis T, Greif R, Iwami T. Willingness to perform bystander cardiopulmonary resuscitation: a scoping review. *Resusc Plus* 2020 Dec;4:100043 [FREE Full text] [doi: [10.1016/j.resplu.2020.100043](https://doi.org/10.1016/j.resplu.2020.100043)] [Medline: [34223318](https://pubmed.ncbi.nlm.nih.gov/34223318/)]

Abbreviations

BLS: basic life support

CHLA: Children's Hospital of Los Angeles

CPR: cardiopulmonary resuscitation

QCPR: Quality CPR

REDCap: Research Electronic Data Capture

SCA: sudden cardiac arrest

VR: virtual reality

Edited by T Leung, G Eysenbach; submitted 05.10.23; peer-reviewed by A Bustillo, S Ricci, E Rodríguez-Higueras, P Vemavarapu; comments to author 16.02.24; revised version received 23.02.24; accepted 21.03.24; published 16.04.24.

Please cite as:

Min HJ, Andler C, Barber ROLB, Chang TP, Abelairas-Gomez C, Knowlin LT, Liu DR, Fijačko N

Virtual Reality for Basic Life Support Training in High School Students: Thematic Analysis of Focus Group Interviews

JMIR XR Spatial Comput 2024;1:e53212

URL: <https://xr.jmir.org/2024/1/e53212>

doi: [10.2196/53212](https://doi.org/10.2196/53212)

PMID:

©Hyoin Jennifer Min, Caroline Andler, Rebecca Ortiz La Banca Barber, Todd P Chang, Cristian Abelairas-Gomez, Laquanda T Knowlin, Deborah R Liu, Nino Fijačko. Originally published in JMIR XR and Spatial Computing (<https://xr.jmir.org>), 16.04.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR XR and Spatial Computing, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Original Paper

Factors Associated With Risky Drinking Decisions in a Virtual Reality Alcohol Prevention Simulation: Structural Equation Model

Robert Hrynyschyn^{1,2}, MPH; Julie Dalgaard Guldager^{3,4}, PhD; Daniel Schulze⁵, PhD; Patricia Bianca Lyk⁶, PhD; Gunver Majgaard⁶, PhD; Christiane Stock^{1,3}, PhD

¹Charité – Universitätsmedizin Berlin, Corporate Member of Freie Universität Berlin and Humboldt-Universität zu Berlin, Institute of Health and Nursing Science, Berlin, Germany

²Leibniz ScienceCampus Bremen Digital Public Health, Bremen, Germany

³Unit for Health Promotion Research, Department of Public Health, University of Southern Denmark, Esbjerg, Denmark

⁴Research Department, University College South Denmark, Haderslev, Denmark

⁵Charité – Universitätsmedizin Berlin, Corporate Member of Freie Universität Berlin and Humboldt-Universität zu Berlin, Institute of Biometry and Clinical Epidemiology, Berlin, Germany

⁶The Maersk Mc-Kinney Moller Institute, Game Development and Learning Technology, University of Southern Denmark, Odense, Denmark

Corresponding Author:

Robert Hrynyschyn, MPH

Charité – Universitätsmedizin Berlin, Corporate Member of Freie Universität Berlin and Humboldt-Universität zu Berlin, Institute of Health and Nursing Science

Augustenburger Platz 1

Berlin, 13353

Germany

Phone: 49 30450529030

Email: robert.hrynyschyn@charite.de

Abstract

Background: Risky alcohol consumption among adolescents is a significant public health concern in most Western countries. Various motives and factors (eg, sensation seeking, gender, reduced self-efficacy) known in the literature are associated with risky drinking decisions in real life. Efforts to tackle risky drinking decisions in real life through skills training to deal with social pressures have been successful. However, interventions of this nature require significant resources. Technological solutions, such as virtual reality (VR), offer advantages, as they enable immersive experiences that replicate real-life scenarios. However, a question persists pertaining to the fidelity of real-world behaviors within virtual environments.

Objective: This study is exploratory and aims to ascertain if the established drinking motives and factors for risky drinking decisions are transferrable to the virtual environment in the simulation game VR FestLab and to uncover determinants linked to risky drinking decisions within the simulation.

Methods: The study analyzed data from the intervention arm of a cluster-randomized study of 161 Danish students aged 14-18 years who tested the virtual alcohol prevention simulation VR FestLab. At baseline and before playing VR FestLab, independent variables such as age, gender, alcohol consumption, use of other drugs, sensation seeking, drinking refusal skills, knowledge of blood alcohol concentration, and refusal communication skills were recorded. The dependent variable, virtual risk decisions, was measured immediately after the gameplay. Confirmatory factor analysis and structural equation modeling were used to examine the latent variables in relation to virtual risk decisions. Moderation analyses for age and gender in relation to the latent characteristics and the primary outcome were also conducted.

Results: The data indicate that 73.9% (119/161) of the participants engaged in binge drinking at least once in their lifetime. The confirmatory factor analysis demonstrated a good fit of the items for their respective constructs; therefore, they were adopted without modification in the structural equation model. The data suggest that individuals with prior alcohol experience are 4 times more likely to engage in virtual risk decisions within the simulated environment (odds ratio 4.31, 95% CI 1.70-10.84; $P=.01$). Knowledge and awareness of blood alcohol concentration were associated with a lower chance to engage in virtual risk decisions (odds ratio 0.32, 95% CI 0.11-0.93; $P=.04$). However, no significant associations were found between virtual risk decisions and other latent variables. Gender and age did not moderate the associations.

Conclusions: The immersive and lifelike properties of VR partially reflected risk-related decisions. However, it remains unclear which factors favor the mapping of real-world behaviors in virtual simulations. Therefore, future research should address the mechanisms underlying behavioral dynamics in virtual simulations and explore the translation of virtual behaviors into real behaviors to gain a comprehensive understanding of the potential of virtual simulations for alcohol prevention.

(*JMIR XR Spatial Comput* 2024;1:e56188) doi:[10.2196/56188](https://doi.org/10.2196/56188)

KEYWORDS

alcohol; prevention; virtual reality; risk behavior; structural equation model

Introduction

Alcohol prevention continues to represent a pertinent public health concern worldwide [1]. Despite witnessing a reduction on a global scale since the establishment of the Millennium Development Goals in 1995, alcohol consumption still contributes to 5% of disability-adjusted life years and 5% of total fatalities [2]. Furthermore, harmful alcohol consumption is pivotal in over 200 diseases and injury conditions [3]. Notably, alcohol prevention remains significant, particularly among adolescents, as indicated by the latest European School Survey Project on Alcohol and Other Drugs report, which reveals that approximately 80% of students aged 15-16 years have experimented with alcohol at least once [4]. Denmark surpasses the European average, with roughly 92% of adolescents having consumed alcohol at least once in their lifetimes [4].

To effectively deter premature substance use among adolescents, targeted alcohol prevention programs prove indispensable [5]. In this context, it is important to consider the motives underlying risky consumption patterns among adolescents. A systematic review conducted by Adan et al [6] revealed an association between risky drinking behavior and specific personality traits. For instance, binge drinking was correlated with increased impulsivity and sensation seeking [6], while Stautz and Cooper [7] and Percy et al [8] established an association between high sensation seeking and an increased likelihood of heavy episodic drinking. Other studies have identified binge drinking as particularly linked to male gender and reduced self-efficacy [9]. Moreover, engagement with other legal or illegal substances, apart from alcohol, correlates with increased risk behavior. Creamer et al [10] demonstrated that using various tobacco products corresponds to heightened risk behavior. Additionally, a correlation exists between cannabis use, drinking-related risk behavior [11], and the frequency of alcohol-related consequences [12].

Given the known drinking motives among adolescents, prevention programs anchored in concepts like inoculation theory [13] and social learning theory [14] advocate for skill enhancement that strengthens resilience against social influences, such as peer pressure for risky behavior. Research involving life skills training in educational institutions underscores the value of cultivating social resistance skills and broader personal and social competencies, leading to decreased cigarette use and enhanced anti-drinking attitudes [15]. Moreover, participants demonstrated higher substance use awareness and skill-related knowledge [15]. Effective refusal communication skills and risk-related knowledge are crucial

components for enhancing the personal and social skills of young people. Refusal communication, which involves the ability to say “no” to substance offers, is essential in reducing substance use and risky behavior. Several studies have demonstrated that individuals with strong refusal skills regarding alcohol misuse exhibit reduced abusive alcohol use [16-18], possess greater knowledge of alcohol misuse prevention, are less susceptible to peer pressure, and have better internal health control [19]. However, in addition to communication skills, it is also crucial for young people to have knowledge about substance use and its effects on the body to assess and avoid risks. Individuals with greater knowledge of substance-related topics may be better equipped to handle risky situations, potentially reducing the likelihood of substance abuse. Various studies have explored the relationship between substance-related knowledge and the reduction of risk behaviors, such as alcohol consumption. Teesson et al [20] conducted a cluster-randomized study in schools and found that combining digital prevention programs that increased alcohol-related knowledge resulted in a reduction in binge drinking. Hasking and Schofield [21] demonstrated that health and alcohol knowledge can strengthen the intention-behavior relationship. Individuals with more alcohol-related knowledge and experience are likely to be better informed about the consequences. Conversely, better-informed adolescents are likely to feel better prepared to minimize the risks of alcohol consumption [21]. Padget et al [22] discovered that increased awareness of the detrimental effects of alcohol on the brain resulted in improved perceptions of harm and subsequent attitudes of alcohol aversion. These improvements had a significant impact on the intention not to use alcohol, but they did not result in a significant reduction in short-term alcohol consumption. Therefore, it is important to note that knowledge about alcohol may be only one of many factors that can influence risk-taking decisions. Risk behaviors are frequently caused by multiple factors, and knowledge about alcohol may only have a partial impact on the development or absence of such behaviors.

Although traditional skills training involving rational alcohol consumption often relies on labor-intensive and costly in-person role-playing, contemporary technological solutions such as virtual reality (VR) have emerged. An intrinsic advantage of VR lies in its capacity to deliver an immersive encounter that faithfully mimics real-life scenarios. By replicating authentic situations, VR prompts participants to enact genuine behaviors within virtual environments [23,24]. Whereas studying real-world behaviors within experimentally controlled settings posed challenges, VR now allows one to scrutinize behaviors within genuine settings and uncover determinants of behavioral intentions [25].

The convergence between VR and real-life behavior might be attributed to presence and immersion. Individuals immersed in VR experiences can subjectively experience a sense of “being there” in the virtual realm. This sense of presence fosters more authentic and realistic behavioral responses akin to real-world conduct [26]. Alcañiz et al [27] reported that comparable neural mechanisms can be triggered in individuals immersed in a virtual world, paralleling experiences in the physical world. Additionally, the increasing realism and interactivity of VR technology play a role. As VR systems advance, they provide heightened sensory input and feedback, including lifelike visuals, haptic responses, and precise motion tracking. These immersive, lifelike elements contribute to greater congruence between VR and real-life behaviors [28]. Moreover, psychological factors such as social presence and adherence to social norms influence VR behavior, as people replicate real-world behaviors due to a sense of social presence and the desire to conform, even within virtual contexts [29].

The immersive, authentic portrayal of virtual environments implies that genuine risk behaviors are likely to manifest in these settings. This conjecture is supported by the findings that, for example, children exhibiting higher risk behavior in road traffic replicate this behavior in a virtual cycling simulation [30].

Nonetheless, reviews indicate that VR’s role in substance use prevention remains limited [31,32]. Thus, a cocreated virtual alcohol prevention simulation (VR FestLab) was developed in 2020 [33]. The VR FestLab application, an educational game simulation, aims to enhance the refusal self-efficacy of adolescents aged 15-18 years who experience social pressure to consume alcohol. Given the scarceness of VR-based alcohol prevention applications [31,32], this study was exploratory and aimed to ascertain if the established drinking motives and factors for risky drinking decisions are transferrable to VR FestLab. A structural equation model was used to uncover determinants linked to risky drinking decisions within the simulation. To this end, the following hypotheses were formulated for testing:

1. Higher sensation seeking is associated with increased virtual risk decisions in the simulation.
2. Enhanced knowledge and awareness of blood alcohol concentration (BAC), refusal communication skills, and drinking refusal skills are linked to reduced virtual risk decisions in the simulation.
3. Prior alcohol experiences are associated with increased virtual risk decisions in the simulation.

Methods

Study Design

The data were collected as part of a longitudinal study that investigated the efficacy of the VR FestLab application. The comprehensive procedure and outcomes of the primary study can be found elsewhere [34]. To achieve this objective, a total of 13 Danish schools were allocated in a 1:1 ratio to either the intervention or control group. The schools assigned to the intervention group engaged with the VR FestLab application, whereas those in the control group played the VR game First

Steps (Meta Platforms Inc). The data set in this study was derived from the 7 schools that were selected as intervention schools only. Data collection transpired within the school premises between August 2020 and December 2020 and then again from April 2021 to May 2021; the latter period was necessitated by COVID-19 restrictions. For the original study [34], a sample size calculation was performed using STATA 15 with a 2-sample *t* test. This resulted in a sample size of 135 individuals for the control group and 135 individuals for the intervention group to yield an intervention effect of Cohen $d=0.44$, with a power of 0.80 using a 2-sided α of .05. The sample size was calculated based on an estimated intraclass correlation for drinking refusal self-efficacy of 0.01 and 45 students per school. Taking into account an estimated attrition of 35%, 420 participants were planned to be recruited for the study. Further information can be found elsewhere [34].

Participants

To enroll adolescents aged between 14 and 18 years, initial contact was established with the administrations of the 7 schools through email. Once the school administrations granted their approval, the study’s objective was presented to the respective classes, emphasizing the confidential and anonymous nature of data collection. In accordance with the principles outlined in the Declaration of Helsinki, all students were duly informed that their participation was voluntary, and they gave written consent prior to their involvement.

Ethical Considerations

The study adhered to Danish standards for the ethical conduct of scientific studies and was approved by the Research Ethics Committee of the University of Southern Denmark in March 2020 (case no 20/5348; date of approval: January 22, 2020). In accordance with the Ethics Committee of the University of Southern Denmark, parental consent was waived, as it is only mandatory for adolescents under the age of 15 years in Denmark [35].

The Virtual Reality Simulation VR FestLab

The Danish VR application, VR FestLab, immerses users in a 360-degree filmed simulation and was specifically designed for adolescents aged between 15 and 18 years. A total of 128 distinct scenes allows users to engage with diverse simulation sequences. This interactive experience commences at the home of a school friend, where they both join in a birthday celebration. Within this simulation, users can navigate through 2 virtual rooms using eye movements. As they move within these spaces, they encounter various scenes, such as engaging in beer pong or participating in a flirting scenario, wherein they are presented with choices of both alcoholic and nonalcoholic beverages. Adhering to the taxonomy outlined in the Behavior Change Wheel [36], the simulation effectively integrates various behavior change functions, including education, training, modeling, and coercion or incentivization. Notably, individuals within the simulation can interact with role models who demonstrate the refusal to consume alcohol. If the user decides to consume alcohol and accepts an alcoholic drinking choice, the choice results in an incremental increase of a BAC bar,

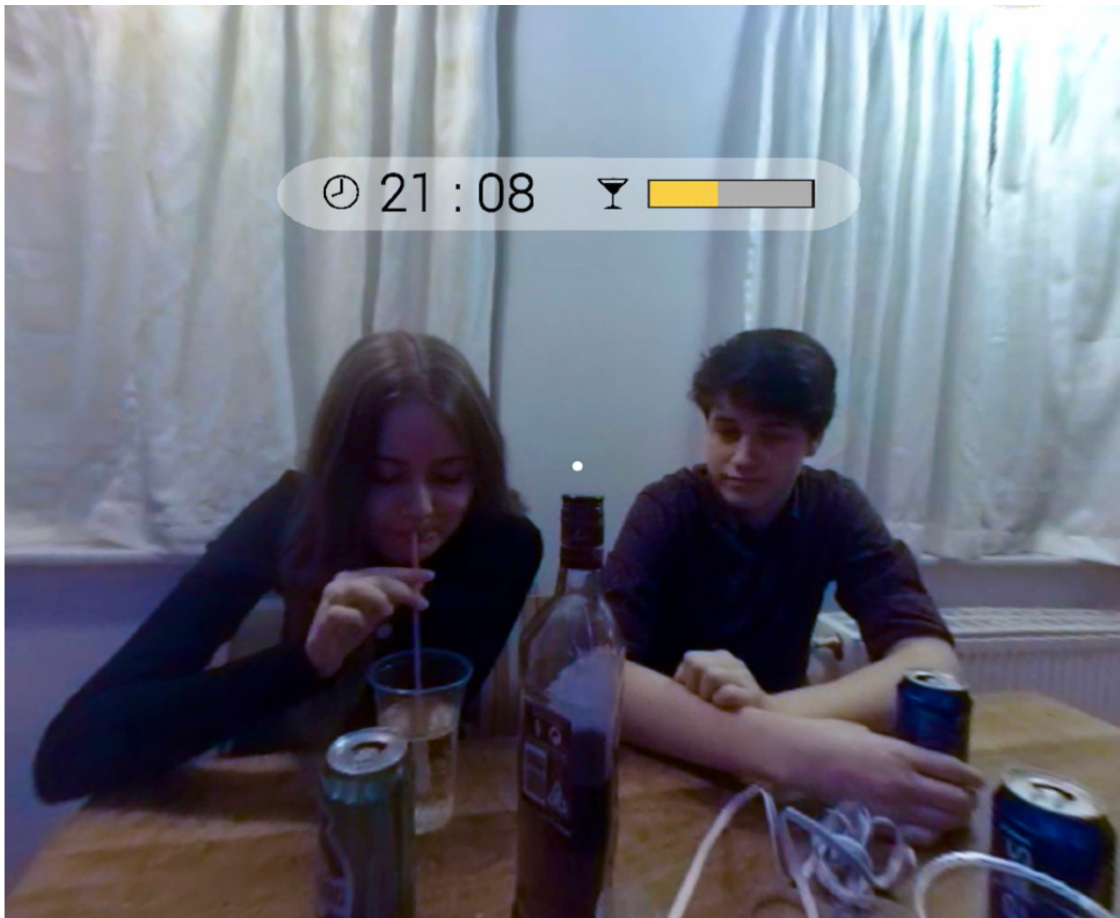
calculated via an algorithm, which is filled in at the top of the screen (see [Figure 1](#), yellow BAC bar at the top of the screen).

This algorithm considers factors like gender, alcohol content in grams, drinking pace, and the average weight of a 16-year-old boy or girl to calculate the BAC [37]. To calculate the exact BAC score, a BAC calculation by Becker and Nielsen [38] was used. The calculation for girls and boys is as follows:



Should the user consume an excessive amount of alcohol within a short span, as determined by the algorithm, they suffer a blackout. This blackout is first portrayed by the camera shaking and a magnifying display of the BAC bar. Following this, within

Figure 1. Screenshot of a scene from the virtual reality simulation FestLab.



Measures

Data were gathered through electronic questionnaires administered during school hours within classroom settings. The questionnaire was developed using the English versions of the respective scales (sensation seeking, drinking refusal skills, refusal communication skills) because no Danish versions were available ([Multimedia Appendix 1](#)). For the other measures (alcohol consumption, other drug consumption, knowledge and awareness of BAC) without existing scales in the literature, the project team created their own questions and items. The English questionnaires were translated to Danish and pretested with 31 students to determine their psychometric characteristics.

the game, the screen turns black, with the user subsequently awakening in a bedroom. In this bedroom, they receive messages that they have blacked out, concluding the simulation.

VR FestLab was pre-installed on Oculus Quest (Meta Platforms Inc) VR devices and handed out to the participants. Before engaging with the simulation, adolescents received instructions on device operation and navigation within the simulation. Following this, adolescents experienced VR FestLab for a maximum of 15 minutes in a classroom session. Depending on the simulation decisions, several rounds could be played during this time. After that, a structured 45-minute group reflection period was moderated by a trained study assistant in the classroom.

Adolescents were tasked with completing the questionnaire before (T0) and after (T1) the intervention. Independent variables, including age, gender, alcohol consumption, other drug consumption, sensation seeking, drinking refusal skills, knowledge and awareness of BAC, and refusal communication skills, were assessed at T0 before the VR FestLab intervention. The dependent variable, virtual risk behavior, was surveyed at T1 following the intervention.

Virtual Risk Decisions

The primary outcome was virtual risk decisions, evaluated through a self-developed question: “Did you pass out at any time during the party?” Answer options were dichotomized (yes/no). Passing out can only be achieved in the simulation

when the number and types of drinks accepted in a given time period resulted in a BAC of 2.0 permille, thus representing several risk decisions. The scenes and participant selections within the simulation were intentionally not recorded nor tracked to afford participants the utmost freedom in their interactions. As a result, the blackout experience in the game could only be assessed verbally. If participants responded affirmatively, it was inferred that the simulation terminated prematurely due to excessive alcohol consumption in a condensed time frame during the simulation.

Age and Gender

Participant gender was dichotomously determined using the question “Are you a girl or a boy? (State what you most identify as right now),” while age was quantified using the question “How old are you?”

Perceived Family Affluence, School Performance, and Health

To gather information on the sociodemographic factors of the participants, the following questions were adapted from the Health Behavior in School-aged Children study [39]: “How well-off do you think your family is?” “What does your class teacher(s) think about your school performance compared to your classmates?” and “Would you say your health is...?”

Alcohol Consumption

Alcohol consumption was estimated with 3 single questions designed by the researchers. The questions “Have you ever drunk alcohol?” “Have you ever been drunk?” and “Have you ever had 5 or more drinks on a single occasion?” could be answered dichotomously (yes/no) by the participants.

Other Drug Consumption

To assess the consumption of substances other than alcohol, 5 customized questions were used. Participants were queried about their usage of cigarettes, hookah, e-cigarettes, snuff, or cannabis. Response options were dichotomized (yes/no).

Sensation Seeking

Sensation seeking was measured using the 8-item Brief Sensation Seeking Scale (BSSS-8) by Hoyle et al [40], which has a Cronbach α of 0.76. Participants answered 8 statements using a 5-point Likert scale, ranging from “strongly disagree” to “strongly agree.” The 8-item scale contains 4 subscales with 2 items each. Subscales, including “thrill and adventure seeking,” “experience seeking,” “disinhibition,” and “boredom susceptibility,” were calculated following the criteria outlined by Hoyle et al [40]. The Cronbach α of the BSSS-8 was 0.76 in our sample.

Drinking Refusal Skills—Social Pressure Subscale

To evaluate drinking refusal skills within the context of peer pressure, the 5-item social pressure subscale of the Drinking Refusal Self-Efficacy Questionnaire (DRSEQ) by Young et al [41], with a Cronbach α of 0.87, was used. Participants responded on a 6-point Likert scale, ranging from “I am very sure I could not resist drinking” to “I am very sure I could resist drinking.” The Cronbach α of the DRSEQ social pressure subscale was 0.88 in our sample.

Knowledge and Awareness of Blood Alcohol Concentration

Knowledge and awareness of BAC was measured using 2 self-constructed items. Participants were prompted to rate the statements “It is easy for me to estimate my own alcohol tolerance” and “I know how much alcohol I can drink before I get drunk” on a 5-point Likert scale, spanning from “strongly disagree” to “strongly agree.”

Refusal Communication Skills

Refusal communication skills were assessed using 2 items drawn from the Alcohol Misuse Prevention Knowledge Questionnaire by Shope et al [19]. Only 2 items from the questionnaire by Shope et al [19] were used because the other questionnaire items do not cover relevant aspects of VR FestLab [34]. Participants were asked to evaluate the statements “If someone offers me a drink of alcohol and I say no, I can make them take no for an answer” and “If my best friends want me to drink beer with them and I don’t want to, I have ways to say no” on a 5-point Likert scale, ranging from “strongly disagree” to “strongly agree.”

Statistical Analysis

Data analysis was performed using the R Studio software package (version 2022.07.2). The 2-step methodology, as outlined by Herting and Costner [42], was used to calculate model fit as the first step and formulate the structural equation model as the second step. Initially, confirmatory factor analysis (CFA) using the lavaan package [43] was carried out to determine the adequacy of the measurement models of the questionnaires. For this purpose, different single-factor models were created and calculated using a diagonally weighted least squares estimator that is suitable for categorical items. Model fit was checked using a chi-square test in combination with other fit indices such as the comparative fit index ($CFI \geq 0.95$), root mean square error of approximation ($RMSEA \leq 0.06$), Tucker-Lewis index (≥ 0.95), and standardized root mean square residual ($SRMR \leq 0.08$) [44].

Subsequently, a structural model with latent variables was calculated to investigate the influence of the constructs (alcohol consumption, other drug consumption, sensation seeking, drinking refusal skills, knowledge and awareness of BAC, and refusal communication skills) on the main outcome (virtual risk decisions) and the correlation of the constructs with age and gender as covariates. In addition, a moderation analysis for gender and age was run. Estimated scores for each latent variable were calculated and subsequently incorporated into a logistic regression model to predict virtual risk decisions.

Results

Participants

A total of 268 students from 7 schools were assigned to the intervention group. Of these, 183 students participated in the baseline survey (T0). The main reasons for dropout between allocation and baseline survey were that 1 complete school (n=36) dropped out, 1 complete school class (n=15) dropped out, and 34 students were not willing to participate or did not

provide consent. After the intervention, 2 additional participants dropped out, resulting in 181 individuals completing the first follow-up questionnaire (T1). The subsequent analysis was based on a complete data set from 161 participants. Additional information on allocation and dropouts can be found elsewhere [34]. To test whether there were differences between respondents at T1 and those who provided complete information at T1 and were included in the analysis, independent *t* tests were conducted for metric variables, and chi-square tests were conducted for nominal and ordinal scaled sociodemographic variables. The analyses showed no differences between the 2 groups in terms of age ($t_{179}=0.61, P=.54$), gender ($\chi^2_1=0.31, P=.58$), and Family Affluence Scale (FAS; $\chi^2_1=0.25, P=.42$). For the chi-square analysis of the FAS between completers and noncompleters,

the prerequisite of cell frequencies above 5 was violated, which is why a Fisher exact test was used.

Sample Characteristics

Table 1 provides an overview of the demographic attributes. Gender distribution was equal, with 78 of the 161 (48.4%) participants being female. The mean age of the sample was 15.6 (SD 0.72) years. Most respondents (143/161, 88.8%) reported low to moderate perceived family affluence, and 62.1% (100/161) rated their perceived school performance as good to very good. Additionally, 79.5% (128/161) reported good to very good health. The majority of respondents (119/161, 73.9%) reported having engaged in binge drinking at some point in their lives.

Table 1. Characteristics of the study population (n=161).

Characteristics	Value
Age (years), mean (SD)	15.6 (0.72)
Gender (female), n (%)	78 (48.4)
Perceived family affluence, n (%)	
Low to medium	143 (88.8)
High to very high	18 (11.2)
Perceived school performance, n (%)	
Good to very good	100 (62.1)
Below average to average	61 (37.9)
Perceived health and well-being, n (%)	
Good to excellent	128 (79.5)
Poor to fair	33 (20.5)
Lifetime binge drinking, n (%)	
Yes	119 (73.9)
No	42 (26.1)

Calculations of Model Fit

The single-factor models generally showed a good fit in the CFA and could therefore be transferred to the structural equation model without adjustments. Sensation seeking provided a mediocre fit, with CFI and RMSEA beyond their cut-offs, while the 90% CI of the RMSEA included the cut-off (see Table 2). The factors “knowledge and awareness of BAC” and “refusal

communication skills” were combined for the CFA for statistical reasons; otherwise, it would not have been possible to determine the fit, as they only contained 2 items each. Finally, the combination of the 2 factors showed high loadings on the individual and superordinate factors, which resulted in good fit values in the CFA. The results of the single-factor models are shown in Table 2 and Figure 2.

Table 2. The goodness of fit indices of the confirmatory factor analysis for single-factor models.

Model	Items	χ^2 test (df)	P value	CFI ^a	TLI ^b	SRMR ^c	RMSEA ^d (90% CI)	P value
Alcohol consumption	3	2.24 (2)	.33	1.00	1.00	0.04	0.03 (0.00-0.16)	.46
Other drug consumption	5	3.02 (5)	.70	1.00	1.00	0.02	0.00 (0.00-0.08)	.84
Sensation seeking	4	7.38 (2)	.03	0.92	0.76	0.05	0.13 (0.04-0.23)	.07
Drinking refusal skills: social pressure subscale	5	19.47 (5)	.01	0.97	0.95	0.03	0.13 (0.08-0.20)	.01
Knowledge of BAC ^e and refusal communication skills	4	1.42 (1)	.23	1.00	0.99	0.02	0.05 (0.00-0.22)	.32

^aCFI: comparative fit index.

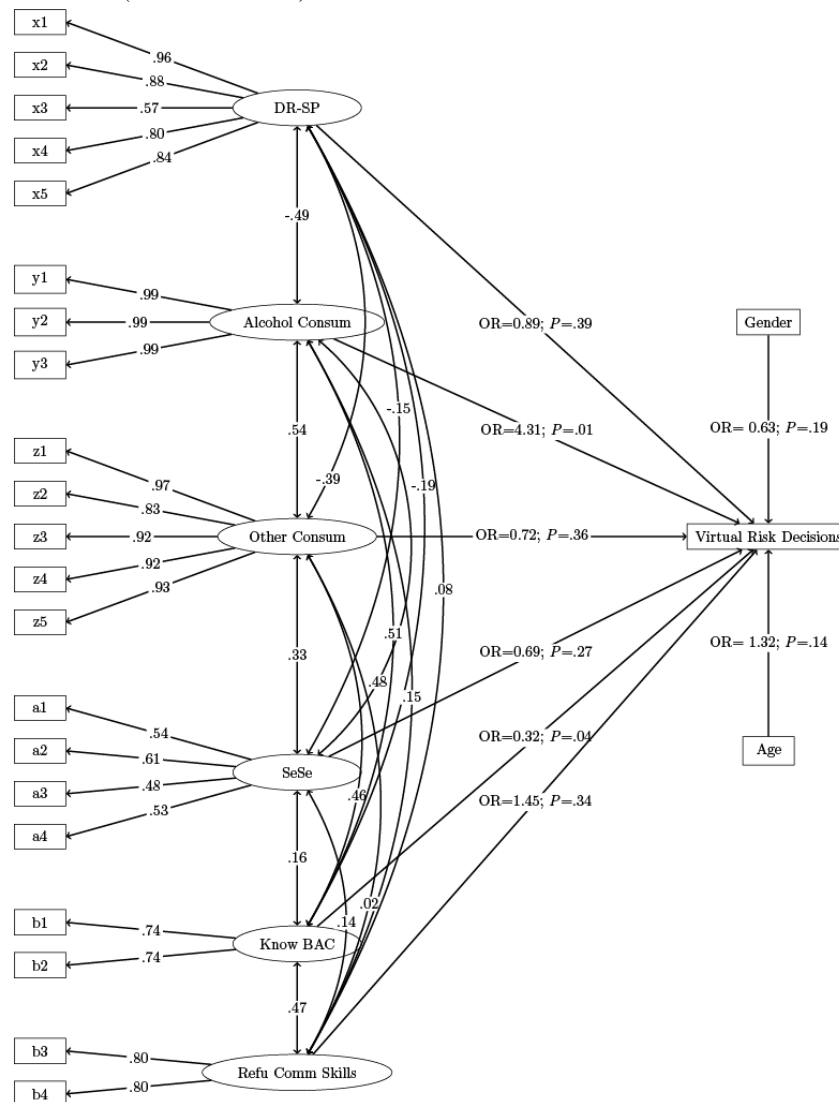
^bTLI: Tucker-Lewis index.

^cSRMR: standardized root mean square residual.

^dRMSEA: root mean square error of approximation.

^eBAC: blood alcohol concentration.

Figure 2. Path model of the relationships between virtual risk decisions and drinking-refusal skills-social pressure (DR-SP), alcohol consumption (Alcohol Consum), other drug consumption (Other Consum), sensation seeking (SeSe), knowledge and awareness of blood alcohol concentration (Know BAC), and refusal communication skills (Refu Comm Skills). OR: odds ratio.



Determinants Linked to Risky Drinking Decisions

A general overview of the bivariate correlations of all variables used in this study can be found in [Multimedia Appendix 2](#). Age and gender were included as covariates without moderation in the structural equation model, as shown in [Figure 2](#). The path model used to test the formulated hypotheses showed an unsatisfying model fit: $\chi^2_{238,161}=422.59$, $P<.001$; CFI=0.94, SRMR=0.12, RMSEA=0.07 (90% CI 0.06-0.08). Nevertheless, we decided to retain the model, because all included measurement models were a priori tested and showed good fit. Due to the explorative nature of the study, the structural model included all possible paths. Therefore, the reason for misfit can be attributed to the cross-loadings of various scales only. As the structural part of the model was the aim of the study, we decided to retain it. [Figure 2](#) shows the tested model. Prior alcohol experiences and knowledge and awareness of BAC were significantly associated with virtual risk decisions in VR FestLab. Participants who reported prior alcohol consumption had a 4.31-fold higher chance of showing virtual risk decisions in the simulation (odds ratio [OR] 4.31, 95% CI 1.70-10.84; $P=.01$). Therefore, hypothesis 3 could be accepted. Apart from that, adolescents with high knowledge and awareness of BAC at baseline were 0.32 times less likely to make virtual risk decisions in the simulation (OR 0.32, 95% CI 0.11-0.93; $P=.04$). Higher social pressure drinking refusal skills (OR 0.89, 95% CI 0.69-1.16; $P=.39$), consumption of other drugs (OR 0.72, 95% CI 0.36-1.45; $P=.36$), sensation seeking (OR 0.69, 95% CI 0.36-1.34; $P=.27$), or refusal communication skills (OR 1.45, 95% CI 0.68-3.10; $P=.34$) showed no significant relationship with virtual risk decisions in the simulation. Therefore, hypotheses 1 had to be rejected, and hypothesis 2 could only be partially confirmed.

Moderation Effects of Gender or Age Regarding Virtual Risk Decisions

Subsequently, we analyzed whether age and gender had a moderating influence on the latent variables. The results of this moderation analysis are presented in [Multimedia Appendix 3](#). All individual moderation analyses for the variables (alcohol consumption, other drug consumption, sensation seeking, drinking refusal skills, knowledge and awareness of BAC, and refusal communication skills) showed no significant moderation. Accordingly, age and gender did not significantly alter the effects of the tested constructs on virtual risk decisions in the simulation. Age and gender also did not significantly influence the dependent variable of virtual risk decisions ([Multimedia Appendix 3](#)).

Discussion

Principal Findings

In summary, the structural equation model exhibited a significant association between prior alcohol experiences and knowledge and awareness of BAC with virtual risk decisions, supporting hypothesis 3. The other initially hypothesized factors (hypotheses 1 and 2), including drinking refusal skills, sensation seeking, refusal communication skills, and consumption of other drugs, did not have significant associations with virtual risk

decisions. Upon exploring moderating factors such as age and gender, no moderation on virtual risk decisions was identified. This study has underscored that prior alcohol experiences are notably linked to virtual risk decisions. Participants who have encountered alcohol and engaged in binge drinking appear to perceive the VR FestLab game as realistically simulating their personal behaviors, leading them to enact these behaviors within the game. Apart from that, it appears that higher knowledge and awareness of BAC is a protective factor and leads to fewer virtual risk decisions in the simulation.

Comparison With Prior Work

These findings align with qualitative insights collected from focus group investigations involving adolescents discussing the simulation [45,46]. Adolescents reported finding the VR simulation remarkably realistic, evoking sensations akin to being present at an actual party [45,46]. The initial participation in VR FestLab possibly aimed to ascertain whether the simulated party aligned with their expectations and whether outcomes matched real-world drinking behaviors. The study's data set does not offer insights into potential variations in behavior between several attempts with VR FestLab. However, it seems plausible that distinct behaviors and strategies would be attempted in subsequent trials, as highlighted by focus group participants in qualitative interviews. The participants expressed the view that VR serves as a medium for experimenting with various behaviors and that repeated engagements with the VR simulation allow for exploring different strategies, such as drinking versus abstaining, while observing the reactions of simulation characters [46]. This points to VR's potential benefit in alcohol prevention, allowing participants to experiment with diverse approaches and behaviors in risky scenarios. This study found a relatively high lifetime prevalence of binge drinking in the group of adolescents aged 14 years to 18 years, at about 73.9% (119/161). In this context, it would be interesting for future studies to investigate the association between previous alcohol consumption and the likelihood of risk decisions in different social environments. These results may also provide hints for further virtual scenarios that can be integrated into the VR FestLab. Hadley et al [47], who combined VR environments with emotion regulation and a risk reduction intervention, also arrived at similar conclusions, indicating that VR, through better simulated contextual cues of risky situations, facilitates the application of different emotion regulation strategies among adolescents. In the real world, such experimentation of behavioral strategies is constrained by the necessity of personally experiencing risky behavior and its consequences, often without the possibility of multiple trials (eg, in the case of blackout).

The hypothesis that individuals with high sensation-seeking tendencies would exhibit elevated virtual risk decisions within the game could not be substantiated by the study's findings. The lack of a significant association between sensation seeking and virtual risk decisions could potentially be attributed to the design of VR FestLab. The game's preventive nature might not have resonated sufficiently with individuals displaying high sensation-seeking behavior. Given that sensation seeking characterizes those seeking diverse, potentially risky experiences [48], the simulated risk behavior in VR FestLab might not have

provided compelling cues for such participants. Participants were aware of the virtual and simulated nature of the risk decisions, possibly leading to the observed absence of virtual risk decisions in the game. This absence could also stem from the absence of personal consequences, such as intoxication, emotional arousal, and sensory perceptions, conveyed through VR FestLab. This lack of stimuli might not engage adolescents with a high sensation-seeking drive. On the contrary, sensation seeking is a multifaceted construct, not exclusively tied to risky behavior. The study by Ravert and Donnellan [49] found that sensation seeking, manifested as a search for stimulation, could also be positively linked to psychological well-being. Furthermore, sensation seeking might have been manifest in nonalcohol-related scenes within VR FestLab (eg, interactions with game characters), rendering the presumed virtual risk decisions unappealing to participants with pronounced sensation-seeking tendencies.

Likewise, drinking refusal self-efficacy skills failed to display an association with reduced virtual risk decisions in this study. Those with higher baseline drinking refusal self-efficacy skills might have opted for less risky drinking decisions within VR FestLab, possibly bypassing activities like beer pong. These observations align with those of the study by Guldager et al [34] that assessed the efficacy of VR FestLab. Although effects were insignificant, a more pronounced increase in drinking refusal skills was noted among participants whose baseline skills lay below the median compared with those above the median. Despite the documented real-world associations between risky behavior and higher drinking refusal skills, drug consumption, and refusal communication skills [50,51], these correlations did not manifest in the virtual world.

Although it was originally hypothesized that higher refusal communication skills would be associated with a reduction in virtual risk decisions, this hypothesis was not supported by this study. It is possible that participants were more exploratory when playing VR FestLab to “just see what happens next” and did not use their refusal communication skills in the simulation to say no to drinking offers. Qualitative interviews with adolescents who played VR FestLab revealed that they felt the peer pressure in the simulation was weaker than in real life [45], which could be a reason why refusal communication skills were not associated with reduced virtual risk decisions in this study.

Apart from that, this study has shown that individuals with higher knowledge and awareness of BAC are less likely to make risky decisions in virtual environments. It is reasonable to assume that those who understand how different drinks affect BAC are less likely to engage in risky decisions in VR FestLab compared with those who cannot accurately assess the effects of BAC. These assumptions are supported by the literature, which indicates that individuals with greater knowledge of low-risk alcohol consumption are more likely to reduce their alcohol intake and make fewer risky decisions [52]. Increased awareness of BAC could enhance risk perception and enable better anticipation and assessment of the consequences of risk decisions. It is possible that individuals without knowledge and awareness of BAC were more willing to experiment in the simulation, leading to an increase in virtual risk-taking decisions. VR FestLab is a prevention program that uses an in-game BAC

bar to illustrate the effects of alcohol-related decisions on BAC. The in-game presentation may help adolescents avoid risky decisions by increasing their knowledge of BAC. Other research [53] using VR in e-cigarette prevention has also shown that virtual prevention simulations can increase substance-related knowledge and harmful perceptions about e-cigarettes.

To our knowledge, this study is the first attempt to examine the relationship between real-life behavior and attitudes and virtual risk decisions in the context of alcohol prevention, making it difficult to contextualize the findings with those of other virtual alcohol prevention studies. The findings illuminate VR's capacity to replicate real-life behavior within simulated environments. Other studies [54-56] using VR in other thematic areas have also concluded that there are links between simulated behavior and real behavior. The combination of prevention and VR within research is relatively novel, necessitating further exploration into leveraging simulated settings for risk behavior prevention and health promotion. Existing studies underscore increasing adoption of VR for prevention and health promotion [57]. Building behavior change interventions and predicting behavioral transformations are challenging in real-world scenarios [58]. Immersive technologies, such as VR, can harness specific attributes like training and realism to facilitate future behavioral change. Nevertheless, the translation of real-life behavior into virtual simulations, along with the potential impact of virtually acquired behavioral patterns on subsequent real-world behavior, remains uncertain. Research suggests that altering an individual's avatar representation in VR influences their behavior and psychological disposition in the real world, an occurrence termed the Proteus effect [24,59]. This phenomenon could also be probed in the context of alcohol prevention, where avatars could shape participants' self-image and preventive behaviors. Addressing these unresolved questions in future studies while delving into the mechanisms at play in virtual simulations could position VR as a valuable asset in prevention and health promotion.

Limitations

In this study, certain limitations must be acknowledged when interpreting the results. First, the applicability of the findings warrants consideration. Participants were drawn from diverse Danish schools, making the results pertinent exclusively to Danish students. Additionally, the recruitment was limited to a specific region within Denmark, implying that adolescents from other regions within Denmark or other countries might exhibit disparate outcomes.

Second, the results should be cautiously approached due to the reliance on self-reported data, which are susceptible to common biases such as respondent bias, extreme responding, and social desirability bias [60]. These potential biases could have influenced and skewed the reported results. The timing of the follow-up data collection (T1), conducted immediately after the intervention, may have influenced the results. Furthermore, this study did not survey risk behaviors that may occur prior to a blackout, such as engaging in sexual activity or driving under the influence of alcohol. Future studies should consider measuring these risk behaviors before a blackout occurs in order to establish a relationship. Specifically, the question about

certain risk decisions may have been biased (eg, experiencing a blackout). The potential for a Hawthorne effect should be considered when interpreting the results, because the students in the intervention group were not blinded and tested the new VR FestLab application. Their knowledge of participation in the study and the aim of VR FestLab can influence their self-assessment of whether they experienced a blackout in the application, which could potentially distort the results. Since there was no content tracking during participants' engagement with the simulation, the navigation patterns within the simulation remain uncharted. Integrating a content log in future analyses could offer deeper insights into participants' usage behavior.

Third, organizational limitations limited the playing time to 15 minutes for each participant. This restriction could have led to variations in the number of rounds played within the simulation, potentially affecting the reported outcomes. Additionally, the controlled setting of the VR FestLab intervention study might have curtailed the expression of extreme behaviors that could

naturally occur among adolescents. This controlled environment may have influenced the observed results.

Conclusions

Despite these limitations, this study illuminates the link between real-life behavior and virtual simulations in alcohol prevention. The significance of prior alcohol experiences in shaping virtual risk decisions underscores the potential of VR to mimic real behaviors. The study highlights VR's potential as a valuable tool for behavior change interventions and health promotion. To harness this potential, future research should delve into mechanisms underpinning behavioral expression in virtual environments. As VR evolves, it presents a promising avenue for health promotion strategies, offering a unique medium to experiment with behaviors in risk-prone scenarios. This research signifies the importance of advancing our understanding of the intersection between human behavior, virtual simulations, and their real-world implications.

Acknowledgments

We thank Kristoffer Drue Knudsen for his literature research and data preparation and Satayesh Lavasani Kjær, Nørgaard Lehnsted, and Maria Busk Damgaard for data collection. We would also like to thank the students, teachers, and principals who supported our research through their active participation.

This research was supported by TrygFonden, Denmark (grant number ID 129372). The funder did not have any involvement in the study design, conduct, or publication of results.

Data Availability

The analyzed data can be accessed from the Zenodo database [61].

Authors' Contributions

CS acquired the funding, provided project administration, and supervised the study. RH, CS, and JDG conceptualized the study, curated the data, and performed the formal analysis. RH, DS, and CS created the visualizations and designed the methodology. JDG, PBL, GM, and CS performed the investigation, and CS, PBL, and GM secured the resources. PBL and GM provided the software. RH, JDG, DS, and CS performed the validation and wrote the original draft of the manuscript. All authors reviewed and edited the manuscript draft.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Investigator-developed questionnaire.

[PDF File (Adobe PDF File), 290 KB - [xr_v1i1e56188_app1.pdf](#)]

Multimedia Appendix 2

Bivariate correlations of all variables.

[PDF File (Adobe PDF File), 212 KB - [xr_v1i1e56188_app2.pdf](#)]

Multimedia Appendix 3

Results of the moderation analyses.

[PDF File (Adobe PDF File), 135 KB - [xr_v1i1e56188_app3.pdf](#)]

References

1. Jernigan DH. Alcohol and public health: failure and opportunity. *Milbank Q* 2023 Apr 25;101(S1):552-578. [doi: [10.1111/1468-0009.12631](#)] [Medline: [37096612](#)]

2. Shield K, Manthey J, Rylett M, Probst C, Wettlaufer A, Parry C, et al. National, regional, and global burdens of disease from 2000 to 2016 attributable to alcohol use: a comparative risk assessment study. *Lancet Public Health* 2020 Jan;5(1):e51-e61 [FREE Full text] [doi: [10.1016/S2468-2667\(19\)30231-2](https://doi.org/10.1016/S2468-2667(19)30231-2)] [Medline: [31910980](https://pubmed.ncbi.nlm.nih.gov/31910980/)]
3. Global status report on alcohol and health 2018. World Health Organization. 2018 Sep 27. URL: <https://www.who.int/publications/i/item/9789241565639> [accessed 2024-04-26]
4. ESPAD Report 2019 — Results from the European School Survey Project on Alcohol and Other Drugs. European School Survey Project on Alcohol and Other Drugs (ESPAD). URL: http://www.espad.org/sites/espad.org/files/2020.3878_EN_04.pdf [accessed 2024-04-26]
5. Foxcroft D, Tsertsvadze A. Universal school-based prevention programs for alcohol misuse in young people. *Cochrane Database Syst Rev* 2011 May 11(5):CD009113 [FREE Full text] [doi: [10.1002/14651858.CD009113](https://doi.org/10.1002/14651858.CD009113)] [Medline: [21563171](https://pubmed.ncbi.nlm.nih.gov/21563171/)]
6. Adan A, Forero DA, Navarro JF. Personality traits related to binge drinking: a systematic review. *Front Psychiatry* 2017;8:134 [FREE Full text] [doi: [10.3389/fpsy.2017.00134](https://doi.org/10.3389/fpsy.2017.00134)] [Medline: [28804465](https://pubmed.ncbi.nlm.nih.gov/28804465/)]
7. Stautz K, Cooper A. Impulsivity-related personality traits and adolescent alcohol use: a meta-analytic review. *Clin Psychol Rev* 2013 Jun;33(4):574-592. [doi: [10.1016/j.cpr.2013.03.003](https://doi.org/10.1016/j.cpr.2013.03.003)] [Medline: [23563081](https://pubmed.ncbi.nlm.nih.gov/23563081/)]
8. Percy A, McKay MT, Cole JC. Interplay between sensation seeking and parental rules in the emergence of heavy episodic drinking. *J Res Adolesc* 2019 Dec 16;29(4):814-821. [doi: [10.1111/jora.12435](https://doi.org/10.1111/jora.12435)] [Medline: [30010228](https://pubmed.ncbi.nlm.nih.gov/30010228/)]
9. Bonar EE, Souweidane MA, Blow FC, Bohnert ASB, Bauermeister JA, Young SD, et al. High-intensity drinking among adolescent and emerging adult risky drinkers. *Subst Abus* 2022;43(1):713-721 [FREE Full text] [doi: [10.1080/08897077.2021.2007513](https://doi.org/10.1080/08897077.2021.2007513)] [Medline: [35100097](https://pubmed.ncbi.nlm.nih.gov/35100097/)]
10. Creamer MR, Portillo GV, Clendennen SL, Perry CL. Is adolescent poly-tobacco use associated with alcohol and other drug use? *Am J Hlth Behav* 2016 Jan 01;40(1):117-122. [doi: [10.5993/ajhb.40.1.13](https://doi.org/10.5993/ajhb.40.1.13)]
11. Vijapur SM, Levy NS, Martins SS. Cannabis use outcomes by past-month binge drinking status in the general United States population. *Drug Alcohol Depend* 2021 Nov 01;228:108997 [FREE Full text] [doi: [10.1016/j.drugalcdep.2021.108997](https://doi.org/10.1016/j.drugalcdep.2021.108997)] [Medline: [34508962](https://pubmed.ncbi.nlm.nih.gov/34508962/)]
12. Gunn RL, Sokolovsky AW, Drohan MM, Boyle HK, Stevens AK, White HR, et al. The role of alcohol and cannabis co-use in drinking rate and its impact on consequences. *Alcohol Clin Exp Res* 2022 Nov 04;46(11):2110-2120 [FREE Full text] [doi: [10.1111/acer.14946](https://doi.org/10.1111/acer.14946)] [Medline: [36124876](https://pubmed.ncbi.nlm.nih.gov/36124876/)]
13. McGuire WJ. Resistance to persuasion conferred by active and passive prior refutation of the same and alternative counterarguments. *The Journal of Abnormal and Social Psychology* 1961 Sep;63(2):326-332. [doi: [10.1037/h0048344](https://doi.org/10.1037/h0048344)]
14. Bandura A. The Social Learning Theory of Aggression. In: Falk RA, Kim SS, editors. *The War System: An Interdisciplinary Approach*. New York, NY: Routledge; 1980:141.
15. Botvin GJ, Griffin KW. Life skills training: a competence enhancement approach to tobacco, alcohol, and drug abuse prevention. In: Scheier LM, editor. *Handbook of Adolescent Drug Use Prevention: Research, Intervention Strategies, and Practice*. Washington, DC: American Psychological Association; 2015:177-196.
16. Shin Y. Narrative engagement and interpersonal communication about substance use on adolescent substance use behaviors: a case study of keepin' it REAL. *West J Commun* 2021 Nov 28;85(3):427-450 [FREE Full text] [doi: [10.1080/10570314.2020.1846074](https://doi.org/10.1080/10570314.2020.1846074)] [Medline: [34248318](https://pubmed.ncbi.nlm.nih.gov/34248318/)]
17. Wynn SR, Schulenberg J, Kloska DD, Laetz VB. The mediating influence of refusal skills in preventing adolescent alcohol misuse. *J Sch Health* 1997 Nov;67(9):390-395. [doi: [10.1111/j.1746-1561.1997.tb07183.x](https://doi.org/10.1111/j.1746-1561.1997.tb07183.x)] [Medline: [9471092](https://pubmed.ncbi.nlm.nih.gov/9471092/)]
18. Donohue B, Van Hasselt VB, Hersen M, Perrin S. Substance refusal skills in a population of adolescents diagnosed with conduct disorder and substance abuse. *Addict Behav* 1999;24(1):37-46. [doi: [10.1016/s0306-4603\(98\)00035-5](https://doi.org/10.1016/s0306-4603(98)00035-5)] [Medline: [10189971](https://pubmed.ncbi.nlm.nih.gov/10189971/)]
19. Shope JT, Copeland LA, Maharg R, Dielman TE, Butchart AT. Assessment of adolescent refusal skills in an alcohol misuse prevention study. *Health Educ Q* 1993 Sep 04;20(3):373-390. [doi: [10.1177/109019819302000308](https://doi.org/10.1177/109019819302000308)] [Medline: [8307761](https://pubmed.ncbi.nlm.nih.gov/8307761/)]
20. Teesson M, Newton NC, Slade T, Chapman C, Birrell L, Mewton L, et al. Combined prevention for substance use, depression, and anxiety in adolescence: a cluster-randomised controlled trial of a digital online intervention. *Lancet Digital Health* 2020 Feb;2(2):e74-e84. [doi: [10.1016/s2589-7500\(19\)30213-4](https://doi.org/10.1016/s2589-7500(19)30213-4)]
21. Hasking P, Schofield L. Examining alcohol consumption with the theory of planned behaviour: Do health and alcohol knowledge play a role? *Psychol Health Med* 2015 Oct 15;20(7):838-845. [doi: [10.1080/13548506.2014.969748](https://doi.org/10.1080/13548506.2014.969748)] [Medline: [25318009](https://pubmed.ncbi.nlm.nih.gov/25318009/)]
22. Padget A, Bell ML, Shamblen SR, Ringwalt CL. Does learning about the effects of alcohol on the developing brain affect children's alcohol use? *Prev Sci* 2006 Sep 22;7(3):293-302. [doi: [10.1007/s1121-006-0030-9](https://doi.org/10.1007/s1121-006-0030-9)] [Medline: [16791519](https://pubmed.ncbi.nlm.nih.gov/16791519/)]
23. Morina N, Ijntema H, Meyerbröker K, Emmelkamp PM. Can virtual reality exposure therapy gains be generalized to real-life? A meta-analysis of studies applying behavioral assessments. *Behav Res Ther* 2015 Nov;74:18-24. [doi: [10.1016/j.brat.2015.08.010](https://doi.org/10.1016/j.brat.2015.08.010)] [Medline: [26355646](https://pubmed.ncbi.nlm.nih.gov/26355646/)]
24. Ratan R, Beyea D, Li BJ, Graciano L. Avatar characteristics induce users' behavioral conformity with small-to-medium effect sizes: a meta-analysis of the proteus effect. *Media Psychology* 2019 Jun 20;23(5):651-675. [doi: [10.1080/15213269.2019.1623698](https://doi.org/10.1080/15213269.2019.1623698)]

25. Bordnick PS, Carter BL, Traylor AC. What virtual reality research in addictions can tell us about the future of obesity assessment and treatment. *J Diabetes Sci Technol* 2011 Mar 01;5(2):265-271 [[FREE Full text](#)] [doi: [10.1177/193229681100500210](https://doi.org/10.1177/193229681100500210)] [Medline: [21527092](https://pubmed.ncbi.nlm.nih.gov/21527092/)]
26. Slater M, Banakou D, Beacco A, Gallego J, Macia-Varela F, Oliva R. A separate reality: an update on place illusion and plausibility in virtual reality. *Front. Virtual Real* 2022 Jun 27;3:1. [doi: [10.3389/frvir.2022.914392](https://doi.org/10.3389/frvir.2022.914392)]
27. Alcañiz M, Rey B, Tembl J, Parkhutik V. A neuroscience approach to virtual reality experience using transcranial doppler monitoring. *Presence: Teleoperators and Virtual Environments* 2009 Apr 01;18(2):97-111. [doi: [10.1162/pres.18.2.97](https://doi.org/10.1162/pres.18.2.97)]
28. Pan X, Hamilton AFDC. Why and how to use virtual reality to study human social interaction: The challenges of exploring a new research landscape. *Br J Psychol* 2018 Aug 05;109(3):395-417 [[FREE Full text](#)] [doi: [10.1111/bjop.12290](https://doi.org/10.1111/bjop.12290)] [Medline: [29504117](https://pubmed.ncbi.nlm.nih.gov/29504117/)]
29. Blascovich J, Loomis J, Beall AC, Swinth KR, Hoyt CL, Bailenson JN. Immersive virtual environment technology as a methodological tool for social psychology. *Psychological Inquiry* 2002 Apr;13(2):103-124. [doi: [10.1207/S15327965PLI1302_01](https://doi.org/10.1207/S15327965PLI1302_01)]
30. Zeuwts LHRH, Vanhuele R, Vansteenkiste P, Deconinck FJA, Lenoir M. Using an immersive virtual reality bicycle simulator to evaluate hazard detection and anticipation of overt and covert traffic situations in young bicyclists. *Virtual Reality* 2023 Jan 20;27(2):1507-1527. [doi: [10.1007/s10055-023-00746-7](https://doi.org/10.1007/s10055-023-00746-7)]
31. Durl J, Dietrich T, Pang B, Potter L, Carter L. Utilising virtual reality in alcohol studies: A systematic review. *Health Education Journal* 2017 Dec 11;77(2):212-225. [doi: [10.1177/0017896917743534](https://doi.org/10.1177/0017896917743534)]
32. Prediger C, Helmer SM, Hrynyschyn R, Stock C. Virtual reality-based alcohol prevention in adolescents: a systematic review. *Adolescents* 2021 Apr 28;1(2):138-150. [doi: [10.3390/adolescents1020011](https://doi.org/10.3390/adolescents1020011)]
33. Vallentin-Holbech L, Dalgaard Guldager J, Dietrich T, Rundle-Thiele S, Majgaard G, Lyk P, et al. Co-creating a virtual alcohol prevention simulation with young people. *Int J Environ Res Public Health* 2020 Feb 09;17(3):1097 [[FREE Full text](#)] [doi: [10.3390/ijerph17031097](https://doi.org/10.3390/ijerph17031097)] [Medline: [32050478](https://pubmed.ncbi.nlm.nih.gov/32050478/)]
34. Guldager JD, Kjær SL, Grittner U, Stock C. Efficacy of the virtual reality intervention on alcohol refusal self-efficacy: a cluster-randomized controlled trial. *Int J Environ Res Public Health* 2022 Mar 10;19(6):3293 [[FREE Full text](#)] [doi: [10.3390/ijerph19063293](https://doi.org/10.3390/ijerph19063293)] [Medline: [35328977](https://pubmed.ncbi.nlm.nih.gov/35328977/)]
35. Child participation in research. European Union Agency for Fundamental Rights. 2014 Nov 06. URL: <https://fra.europa.eu/en/publication/2019/child-participation-research> [accessed 2024-04-29]
36. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci* 2011 Apr 23;6:42 [[FREE Full text](#)] [doi: [10.1186/1748-5908-6-42](https://doi.org/10.1186/1748-5908-6-42)] [Medline: [21513547](https://pubmed.ncbi.nlm.nih.gov/21513547/)]
37. Lyk PB, Majgaard G, Vallentin-Holbech L, Guldager JD, Dietrich T, Rundle-Thiele S, et al. Co-designing and learning in virtual reality: development of tool for alcohol resistance training. *ECEL* 2020 Jul 01;18(3):1. [doi: [10.34190/ejel.20.18.3.002](https://doi.org/10.34190/ejel.20.18.3.002)]
38. Becker U, Nielsen AS. Alkohol, fakta om virkning. *Sundhed*. 2023 Dec 01. URL: <https://www.sundhed.dk/borger/patienthaandbogen/psyke/sygdomme/alkohol/alkohol-fakta-om-virkning/> [accessed 2024-04-26]
39. Currie C, Inchley J, Molcho M, Lenzi M, Veselska Z, Wild F. Health behaviour in school-aged children (HBSC) study protocol: background, methodology and mandatory items for the 2013/14 survey. St Andrews, United Kingdom: Child and Adolescent Health Research Unit (CAHRU); 2014.
40. Hoyle RH, Stephenson MT, Palmgreen P, Lorch EP, Donohew R. Reliability and validity of a brief measure of sensation seeking. *Personality and Individual Differences* 2002 Feb;32(3):401-414. [doi: [10.1016/S0191-8869\(01\)00032-0](https://doi.org/10.1016/S0191-8869(01)00032-0)]
41. Young RM, Hasking PA, Oei TP, Loveday W. Validation of the Drinking Refusal Self-Efficacy Questionnaire--Revised in an Adolescent Sample (DRSEQ-RA). *Addict Behav* 2007 Apr;32(4):862-868. [doi: [10.1016/j.addbeh.2006.07.001](https://doi.org/10.1016/j.addbeh.2006.07.001)] [Medline: [16919885](https://pubmed.ncbi.nlm.nih.gov/16919885/)]
42. Herting JR, Costner HL. Another Perspective on "The Proper Number of Factors" and the Appropriate Number of Steps. *Structural Equation Modeling Multidisciplinary J* 2000 Jan;7(1):92-110. [doi: [10.1207/s15328007sem0701_05](https://doi.org/10.1207/s15328007sem0701_05)]
43. Rosseel Y. lavaan: a package for structural equation modeling. *J Stat Soft* 2012;48(2):1. [doi: [10.18637/JSS.V048.I02](https://doi.org/10.18637/JSS.V048.I02)]
44. Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modeling Multidisciplinary J* 1999 Jan;6(1):1-55. [doi: [10.1080/10705519909540118](https://doi.org/10.1080/10705519909540118)]
45. Guldager JD, Kjær SL, Lyk P, Dietrich T, Rundle-Thiele S, Majgaard G, et al. User experiences with a virtual alcohol prevention simulation for Danish adolescents. *Int J Environ Res Public Health* 2020 Sep 23;17(19):6945 [[FREE Full text](#)] [doi: [10.3390/ijerph17196945](https://doi.org/10.3390/ijerph17196945)] [Medline: [32977501](https://pubmed.ncbi.nlm.nih.gov/32977501/)]
46. Hrynyschyn R, Prediger C, Lyk P, Majgaard G, Helmer SM, Stock C. Adolescents' perceptions and user experiences with a virtual reality-based alcohol prevention tool in Germany: A focus group study. *Front Public Health* 2023 Mar 10;11:1054015 [[FREE Full text](#)] [doi: [10.3389/fpubh.2023.1054015](https://doi.org/10.3389/fpubh.2023.1054015)] [Medline: [36969627](https://pubmed.ncbi.nlm.nih.gov/36969627/)]
47. Hadley W, Houck C, Brown LK, Spitalnick JS, Ferrer M, Barker D. Moving beyond role-play: evaluating the use of virtual reality to teach emotion regulation for the prevention of adolescent risk behavior within a randomized pilot trial. *J Pediatr Psychol* 2019 May 01;44(4):425-435 [[FREE Full text](#)] [doi: [10.1093/jpepsy/jsy092](https://doi.org/10.1093/jpepsy/jsy092)] [Medline: [30551157](https://pubmed.ncbi.nlm.nih.gov/30551157/)]
48. Zuckerman M, Kolin EA, Price L, Zoob I. Development of a sensation-seeking scale. *Journal of Consulting Psychology* 1964;28(6):477-482. [doi: [10.1037/t03439-000](https://doi.org/10.1037/t03439-000)]

49. Ravert RD, Donnellan MB. Impulsivity and sensation seeking: differing associations with psychological well-being. *Applied Research Quality Life* 2020 Mar 31;16(4):1503-1515. [doi: [10.1007/s11482-020-09829-y](https://doi.org/10.1007/s11482-020-09829-y)]
50. Oei TP, Morawska A. A cognitive model of binge drinking: the influence of alcohol expectancies and drinking refusal self-efficacy. *Addict Behav* 2004 Jan;29(1):159-179. [doi: [10.1016/s0306-4603\(03\)00076-5](https://doi.org/10.1016/s0306-4603(03)00076-5)] [Medline: [14667427](https://pubmed.ncbi.nlm.nih.gov/14667427/)]
51. Botvin GJ, Griffin KW, Paul E, Macaulay AP. Preventing tobacco and alcohol use among elementary school students through life skills training. *Journal of Child & Adolescent Substance Abuse* 2003 Mar;12(4):1-17. [doi: [10.1300/j029v12n04_01](https://doi.org/10.1300/j029v12n04_01)]
52. Islam MM, Hoffmann MW, Rahman MB. Knowledge of low-risk drinking and its relationship with a reduction in alcohol consumption: Results from six waves of an Australian national survey. *Addict Behav* 2019 Aug;95:172-177. [doi: [10.1016/j.addbeh.2019.03.016](https://doi.org/10.1016/j.addbeh.2019.03.016)] [Medline: [30928662](https://pubmed.ncbi.nlm.nih.gov/30928662/)]
53. Weser VU, Duncan LR, Sands BE, Schartmann A, Jacobo S, François B, et al. Evaluation of a virtual reality E-cigarette prevention game for adolescents. *Addict Behav* 2021 Nov;122:107027. [doi: [10.1016/j.addbeh.2021.107027](https://doi.org/10.1016/j.addbeh.2021.107027)] [Medline: [34225030](https://pubmed.ncbi.nlm.nih.gov/34225030/)]
54. Wang L, Christensen JL, Jeong DC, Miller LC. Virtual prognostication: when virtual alcohol choices predict change in alcohol consumption over 6-months. *Comput Human Behav* 2019 Jan;90:388-396 [FREE Full text] [doi: [10.1016/j.chb.2018.08.025](https://doi.org/10.1016/j.chb.2018.08.025)] [Medline: [30906112](https://pubmed.ncbi.nlm.nih.gov/30906112/)]
55. Real FJ, Whitehead M, Ollberding NJ, Rosen BL, Meisman A, Crosby LE, et al. A virtual reality curriculum to enhance residents' behavioral health anticipatory guidance skills: a pilot trial. *Acad Pediatr* 2023 Jan;23(1):185-192. [doi: [10.1016/j.acap.2022.07.011](https://doi.org/10.1016/j.acap.2022.07.011)] [Medline: [35870801](https://pubmed.ncbi.nlm.nih.gov/35870801/)]
56. Thomas JG, Goldstein CM, Bond DS, Hadley W, Tuerk PW. Web-based virtual reality to enhance behavioural skills training and weight loss in a commercial online weight management programme: The Experience Success randomized trial. *Obes Sci Pract* 2020 Dec 27;6(6):587-595 [FREE Full text] [doi: [10.1002/osp4.451](https://doi.org/10.1002/osp4.451)] [Medline: [33354337](https://pubmed.ncbi.nlm.nih.gov/33354337/)]
57. Buttazzoni A, Parker A, Minaker L. Investigating the mental health implications of urban environments with neuroscientific methods and mobile technologies: A systematic literature review. *Health Place* 2021 Jul;70:102597. [doi: [10.1016/j.healthplace.2021.102597](https://doi.org/10.1016/j.healthplace.2021.102597)] [Medline: [34107446](https://pubmed.ncbi.nlm.nih.gov/34107446/)]
58. Davis R, Campbell R, Hildon Z, Hobbs L, Michie S. Theories of behaviour and behaviour change across the social and behavioural sciences: a scoping review. *Health Psychol Rev* 2015;9(3):323-344 [FREE Full text] [doi: [10.1080/17437199.2014.941722](https://doi.org/10.1080/17437199.2014.941722)] [Medline: [25104107](https://pubmed.ncbi.nlm.nih.gov/25104107/)]
59. Yee N, Bailenson J. The Proteus effect: the effect of transformed self-representation on behavior. *Human Comm Res* 2007 Jul;33(3):271-290. [doi: [10.1111/j.1468-2958.2007.00299.x](https://doi.org/10.1111/j.1468-2958.2007.00299.x)]
60. Rosenman R, Tennekoon V, Hill LG. Measuring bias in self-reported data. *IJBHR* 2011;2(4):320. [doi: [10.1504/ijbhr.2011.043414](https://doi.org/10.1504/ijbhr.2011.043414)]
61. Stock C, Hrynyschyn R, Guldager JD. Dataset for the publication: Factors associated with risky drinking decisions in a virtual reality alcohol prevention simulation: A structural equation model. Zenodo. 2023 Aug 23. URL: <https://zenodo.org/records/8276273> [accessed 2024-04-30]

Abbreviations

- BAC:** blood alcohol concentration
- BSSS:** Brief Sensation Seeking Scale
- CFA:** confirmatory factor analysis
- CFI:** comparative fit index
- DRSEQ:** Drinking Refusal Self-Efficacy Questionnaire
- FAS:** Family Affluence Scale
- OR:** odds ratio
- RMSEA:** root mean square error of approximation
- SRMR:** standardized root mean square residual
- TLI:** Tucker-Lewis index
- VR:** virtual reality

Edited by T Leung; submitted 09.01.24; peer-reviewed by W Hadley, J Boissoneault, V Girishan Prabhu; comments to author 18.02.24; revised version received 09.03.24; accepted 21.04.24; published 06.05.24.

Please cite as:

Hrynyschyn R, Guldager JD, Schulze D, Lyk PB, Majgaard G, Stock C

Factors Associated With Risky Drinking Decisions in a Virtual Reality Alcohol Prevention Simulation: Structural Equation Model

JMIR XR Spatial Comput 2024;1:e56188

URL: <https://xr.jmir.org/2024/1/e56188>

doi: [10.2196/56188](https://doi.org/10.2196/56188)

PMID:

©Robert Hrynyschyn, Julie Dalgaard Guldager, Daniel Schulze, Patricia Bianca Lyk, Gunver Majgaard, Christiane Stock. Originally published in JMIR XR and Spatial Computing (<https://xr.jmir.org>), 06.05.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR XR and Spatial Computing, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Original Paper

Exploring How Virtual Reality Could Be Used to Treat Eating Disorders: Qualitative Study of People With Eating Disorders and Clinicians Who Treat Them

Helen Bould^{1,2,3,4}, BMBCCh, DPhil; Mari-Rose Kennedy⁵, PhD; Ian Penton-Voak^{3,6}, PhD; Lisa May Thomas^{7,8}, PhD; Jon Bird⁹, PhD; Lucy Biddle^{1,3,5}, PhD

¹Centre for Academic Mental Health, Population Health Sciences, Bristol Medical School, University of Bristol, Bristol, United Kingdom

²Medical Research Council Integrative Epidemiology Unit, University of Bristol, Bristol, United Kingdom

³NIHR Biomedical Research Centre, University Hospitals Bristol and Weston NHS Foundation Trust, University of Bristol, Bristol, United Kingdom

⁴Gloucestershire Health and Care NHS Foundation Trust, Gloucester, United Kingdom

⁵NIHR Applied Research Collaboration West at University Hospitals Bristol and Weston NHS Foundation Trust, Bristol, United Kingdom

⁶School of Psychological Science, University of Bristol, Bristol, United Kingdom

⁷School for Policy Studies, Centre for Sociodigital Futures, University of Bristol, Bristol, United Kingdom

⁸Pervasive Media Studio, Bristol, United Kingdom

⁹Department of Computer Science, University of Bristol, Bristol, United Kingdom

Corresponding Author:

Helen Bould, BMBCCh, DPhil

Centre for Academic Mental Health

Population Health Sciences, Bristol Medical School

University of Bristol

Oakfield House

Oakfield Grove

Bristol, BS8 2BN

United Kingdom

Phone: 44 (0)117 9289000

Email: helen.bould@bristol.ac.uk

Abstract

Background: Immersive virtual reality (VR) interventions are being developed and trialed for use in the treatment of eating disorders. However, little work has explored the opinions of people with eating disorders, or the clinicians who treat them, on the possible use of VR in this context.

Objective: This study aims to use qualitative methodology to explore the views of people with eating disorders, and clinicians who treat them, on the possible use of VR in the treatment of eating disorders.

Methods: We conducted a series of focus groups and interviews with people with lived experience of eating disorders and clinicians on their views about VR and how it could potentially be used in the treatment of eating disorders. People with lived experience of eating disorders were recruited between October and December 2020, with focus groups held online between November 2020 and February 2021; clinicians were recruited in September 2021 and interviewed between September and October 2021. We took a thematic approach to analyzing the resulting qualitative data.

Results: We conducted 3 focus groups with 10 individuals with a current or previous eating disorder, 2 focus groups with 4 participants, and 1 with 2 participants. We held individual interviews with 4 clinicians experienced in treating people with eating disorders. Clinicians were all interviewed one-to-one because of difficulties in scheduling mutually convenient groups. We describe themes around representing the body in VR, potential therapeutic uses for VR, the strengths and limitations of VR in this context, and the practicalities of delivering VR therapy. Suggested therapeutic uses were to practice challenging situations around food-related and weight/appearance-related scenarios and interactions, to retrain attention, the representation of the body, to represent the eating disorder, for psychoeducation, and to enable therapeutic conversations with oneself. There was a substantial agreement between the groups on these themes.

Conclusions: People with lived experience of eating disorders and clinicians with experience in treating eating disorders generated many ideas as to how VR could be used as a part of eating disorders treatment. They were also aware of potential limitations and expressed the need for caution around how bodies are represented in a VR setting.

(*JMIR XR Spatial Comput* 2024;1:e47382) doi:[10.2196/47382](https://doi.org/10.2196/47382)

KEYWORDS

eating disorders; virtual reality; anorexia nervosa; bulimia nervosa; EDNOS; treatment; immersive; clinicians; qualitative data; psychoeducation; therapeutic; limitations

Introduction

Eating disorders are serious mental illnesses, affecting around 8% of women and 2% of men at some point in their lives [1]. They have substantial physical [2,3] and psychiatric [4] comorbidities, with anorexia nervosa having the highest mortality of any psychiatric illness [5]. Nationally representative population data from England show that rates of possible eating disorders in adolescents almost doubled from 6.7% in 2017 to 13.0% in 2021 [6]. Meanwhile, at 10-year follow-ups, only one-third of those with anorexia nervosa and two-thirds of those with bulimia nervosa have fully recovered [7], and rates of relapse are up to 50% in those with anorexia nervosa [8]. New treatments are thus urgently needed.

Virtual reality (VR), a technology which “immerses users in a fully digital environment through a headset or surrounding display” (p. 3) [9] is a candidate modality for such novel treatments. VR shows promise in treating mental illnesses, with studies demonstrating efficacy in treating phobias, including fear of heights [10] and spiders [11]; anxiety disorders [12]; and avoidance and distress in people with psychosis [13]. Emerging evidence suggests that VR can be useful in the treatment of eating disorders, with a meta-analysis showing reductions in binge frequency and body dissatisfaction in binge-purge and binge-eating disorders [14]. Some evidence also suggests that exposure to a larger version of one’s own body in VR may be a useful addition to the treatment of anorexia nervosa [15,16].

One problem with the currently established treatments for eating disorders is the high rate of dropouts. Even in randomized controlled trials, as many as 40% of participants do not complete treatment for anorexia nervosa [17]. For new treatments to have the best chance of being acceptable to patients, a prerequisite for efficacy, they should be designed in collaboration with the patient group for whom they are intended. To our knowledge, no previous work has explored the perspectives of people with lived experience of eating disorders on the potential use of VR in their treatment.

There is also a longstanding acknowledgment of the difficulty in ensuring that patients receive evidence-based treatments, variously termed an “evidence to practice gap” [18], “implementation problem” [19], or “second translational gap” [20]. This is a particular challenge for complex interventions. To avoid or shorten this gap, it is argued that new interventions should be designed with implementation in mind and that frontline clinicians should also be involved in novel intervention design from the outset. In relation to the growing field of

developing clinical interventions using VR, an international working group of Virtual Reality Clinical Outcomes Research Experts also state that “it is vital to include the patients’ voice early and often in the development of VR treatments” (p. 2), as well as seeking input from health care providers, to design acceptable, feasible, and effective VR treatments [21].

We therefore set out to conduct a series of focus groups and one-to-one interviews with both people with lived experience of eating disorders and, separately, the clinicians who treat them. We explored their thoughts about using a VR environment, including their ideas about the potential therapeutic uses of VR, and any concerns or worries about risks.

Methods

Participants

We recruited participants with lived experience of eating disorders via social media, through the UK eating disorders charity the Somerset and Wessex Eating Disorder Association, and by contacting those on a list of research-interested individuals with eating disorders held by HB. We recruited clinicians with experience in treating people with eating disorders via social media and by snowballing via professional contacts. Potentially interested participants completed a brief online screening questionnaire via SurveyMonkey (SurveyMonkey Inc.; [Multimedia Appendices 1 and 2](#)) to check they met inclusion criteria.

Inclusion criteria for people with lived experience of an eating disorder required that they be aged 16 or over, and have any current or previous eating disorder (eg, anorexia nervosa, bulimia nervosa, binge eating disorder, or other specified feeding or eating disorder). We did not specify that participants must be based in the United Kingdom. We excluded people currently being treated as an inpatient in a hospital. Inclusion criteria for clinicians required that they be a health professional with at least six months’ experience in treating people with eating disorders. Inclusion criteria for both groups required fluency in English (due to a lack of funding for translators) and the ability to access a private space with an internet-enabled device via which they could join an online focus group or interview. We did not require participants to have any previous experience of using VR. We conducted interviews and focus groups online as a result of constraints around in-person research during the COVID-19 pandemic. All participants provided written consent and were offered a £10 (US \$12.5) shopping voucher to thank them for their time.

After recruiting the first 8 eligible participants who were women and who responded to follow-up emails, we excluded subsequent

responders who were women to include men. All eligible clinicians who responded to follow-up emails were included.

People with lived experience of eating disorders were recruited between October and December 2020, and focus groups were held online between November 2020 and February 2021; clinicians were recruited in September 2021 and interviewed between September and October 2021.

Ethics Approval

The study was approved by the Faculty of Health Science Research Ethics Committee, University of Bristol (reference number 7545).

Procedure

We collected brief demographic data, including age, gender (participants were asked “How would you describe your gender?”) and ethnicity, duration of current or previous eating disorder (for people with lived experience of eating disorders), professional background (for clinicians), and duration of experience in treating people with eating disorders (clinicians).

Interview and focus group discussion topics were informed by a topic guide (available in [Multimedia Appendices 3 and 4](#)). We also shared some slides with images of VR headsets and from some VR games and current VR interventions for those with fear of heights and psychosis (see [Multimedia Appendix 5](#)). We used open-ended questioning and follow-up probes to explore participants’ ideas in detail and also allowed them to suggest and discuss issues of importance that were not included in the topic guide. All interviews and focus groups were then conducted via videoconferencing software (Microsoft Teams; Microsoft Corporation), audio-recorded on an encrypted recording device, and transcribed verbatim. Authors HB and LB ran the focus groups together, enabling one of them to monitor the written “chat” function and provide support to any distressed participant if necessary. HB conducted the one-to-one interviews alone.

Analysis

We used a thematic approach, with MRK, HB, and LB all taking part in coding. These coauthors brought differing perspectives and expertise to the data: LB as an associate professor in qualitative mental health research, MRK as a more junior qualitative researcher in health and ethics, and HB as a child and adolescent psychiatrist with research and clinical expertise in eating disorders. HB’s clinical expertise likely influenced the lines of inquiry taken within the interviews and allowed greater probing of the participants, but may have introduced bias. This clinical perspective is likely to have been

counterbalanced by LB and MRK approaching the interviews and analyses from their complementary and nonclinical perspectives. MRK conducted the initial coding of 2 focus groups. Sections of the data from these 2 focus groups were then coded separately by coauthors LB and HB, with high levels of concordance in the coding. LB, HB, and MRK held a series of meetings to finalize the coding frame, and MRK then applied this frame to the final focus group. As the coding frame evolved, codes were grouped to derive themes and subthemes.

MRK then applied the same coding frame to the clinician interviews. Subsections of these interviews were coded by LB and HB, and further meetings were held between HB, MRK, and LB to finalize agreement on these codes. The coding frame evolved through the addition of new ideas from clinician participants and through discussion, we grouped the codes into themes and subthemes. MRK then wrote a descriptive account of the themes and subthemes to explore in detail their content and relationships.

Results

Participant Characteristics

A total of 14 participants contributed to these data: 10 people with lived experience of eating disorders and 4 clinicians ([Table 1](#)). People with lived experience of eating disorders included both people with a current eating disorder and people who have recovered. The length of illness varied from 3 to 20 years. Clinicians came from a range of professional backgrounds and had between 2 and 15 years’ experience of working with people with lived experience of eating disorders. We recruited men and women in both groups.

The screening survey was completed by 31 respondents with lived experience: 5 did not fully complete the survey or supply contact details, 8 did not respond to email invitations to join a focus group, and 8 were women who responded after we had held 2 focus groups with women and were purposively sampling participants who were men. These 21 respondents were therefore not included, and the remaining 10 joined a focus group. Nine clinicians completed the screening questionnaire: 3 did not complete it fully or supply contact details, and 2 did not respond to email invitations.

We held a total of 3 focus groups for people with lived experience of eating disorders: 2 with 4 participants and 1 with 2 participants. As a result of difficulties in finding mutually convenient times, we were not able to hold clinician focus groups and instead held a series of one-to-one interviews.

Table 1. Participant characteristics.

Characteristics	Values
People with lived experience of eating disorders (n=10)	
Gender	
Women, n	8
Men, n	2
Age (years), range	19-37
Ethnicity	
White/White British, n	10
Current eating disorders	
Current anorexia nervosa, n	4
Current bulimia nervosa, n	2
Duration (years), range	3-20
Previous eating disorders	
Previous anorexia nervosa, n	5
Previous eating disorder not otherwise specified, n	1
Duration (years), range	5-16
Recovered from eating disorders, n	
Duration (years), range	0.25-6
Clinicians (n=4)	
Gender	
Women, n	3
Men, n	1
Age (years)	
25-34, n	1
35-44, n	1
45-54, n	1
55-64, n	1
Ethnicity	
White/White British, n	4
Duration (years) of clinical experience with people with eating disorders, range	2-15
Professional background	
Clinical psychologist, n	1
Counselor, n	1
Family therapist, n	1
Mental health nurse, n	1

Themes

Overview

We describe the core themes: Representing the Self, Strengths and Limitations of VR, Potential VR Interventions, and Practicalities of Delivering VR Therapy. Quotes from people with lived experience of an eating disorder are followed by PWLE, and the number indicates their group (members of groups 1 and 2 were all women; and members of group 3 were

men); quotes from clinicians are indicated CL. Most participants reported having tried VR as entertainment, and those who had not reported that they were willing to try it.

Representing the Self

Everyone acknowledged that deciding how best to represent the self in a VR setting was challenging (“one of the really tough questions” [PWLE3]); “need[s] to be very carefully...done” [CL4]).

People with lived experience of eating disorders felt comfortable with a first-person perspective: “I quite like the idea of just it being from my perspective, so just seeing your feet and hands” [PWLE1]; “I was imagining that you wouldn’t see yourself...you’d see what you would normally see if you were walking around” [PWLE2]. Clinicians agreed: “if I had an eating disorder, I’d probably prefer not having my body [in the VR setting], just having my hands” [CL1], also suggesting that this would increase a sense of embodiment: “[if] I just see my hands, that feels more real because when I’m me, I can’t see my body, unless I look down my body” [CL1]. Some people with lived experience of eating disorders highlighted the importance of accuracy and realism to enable them to suspend disbelief, including representing correct skin color and gender even if only representing a hand.

Some people with lived experience of eating disorders were concerned about the possibility of their whole body being represented, for example, from a third-person perspective or in a mirror, which they felt may exacerbate self-criticism and create risk: “maybe I’ll see something on VR that I’ve never seen in real life and it makes me worse...you might go, wow, I really do look shit in that outfit or you know nude or whatever” [PWLE2]; “with eating disorders being the beast they are, anything that would maybe feed into that kind of inner critic, or that sort of obsession with our sort of external appearance, it would have to be handled very sensitively...for it not to risk causing more harm than good” [PWLE1]. They were also concerned about how accurate images might be created: “wouldn’t you have to take full body photos of people...which in itself I think could be quite difficult” [PWLE1].

There was some concern that an accurately represented body might be distracting: “you would then become too focussed on what it looked like, and then ignore the job in hand” [PWLE2], but participants in both groups also discussed that this itself could form part of treatment (see the “Potential VR Interventions” section).

People with lived experience of eating disorders discussed alternative suggestions as to how their bodies may be represented, such as a “cartoon”-type avatar [PWLE2] or animal [PWLE1]. While such alternatives might be useful to avoid “getting hung up” [PWLE1] on one’s image, they were largely dismissed as unrealistic or silly, and possibly preventing engagement: “I think seeing me like a kind of panda pinballing around...I just wouldn’t...feel like I could get on board with it” [PWLE1].

Representing the self in an abstract form was also suggested and again felt to have therapeutic potential (see the “Potential VR Interventions” section): “maybe they could be shapes, maybe they could be manifested in different things, like personifications, emotions...I actually think that could be part of the process” [PWLE3].

Despite prompting, clinicians expressed few views on how representation should be achieved, tending to share the belief that “it’s best to go with their [PWLE] visualisation, because then it has more meaning” [CL1]. However, participants in both groups agreed the actual process of creating a representation of self could be challenging if this presented patients with excessive

choice: “I would be distracted by worrying what my virtual [cartoon avatar] self looked like if it was down to me [to make it] or whether it was down to someone else to generate me then I might get offended” [PWLE1]. One clinician suggested this process could be simplified: “so that we didn’t have endless conversations about choice...there’s a bit of me that would go for a menu of what somebody looks like so they could choose a torso or...a torso or legs or a face...or the menu would just be certain kinds of figures” [CL3]. One clinician also raised the point that it may be important to discuss the process of leaving VR to return to one’s own real body: “we’re not going to be that avatar so, how do we then come back out into the real world and reconnect with who we really are, even the bits we don’t like” [CL1].

Strengths of VR

People with lived experience of eating disorders and clinicians were excited about the potential of using VR in treating eating disorders and felt it may be more engaging than other treatments: “I would be more motivated to do that as my homework than my mood diaries or my thought diaries” [PWLE3]; “I’d be really interested in it, definitely like give it a go, I imagine young people would just engage very well in it” [CL4].

Participants described the strength of creating realistic situations, which nevertheless were not actually real and so could provide a safe space to practice: “knowing it’s not real, but also it’s simulating something that is real so it would be a very good first approach to...expose somebody to something scary” [PWLE1]; “a gentle form of exposure work” [CL3]. One clinician [CL1] wondered if this might be particularly valuable for some groups of patients, suggesting that those who are autistic or anxious may find it easier to engage in a “real” activity than a face-to-face conversation.

Participants noted that in some ways VR was “better” than real life because it is a “controlled environment” [PWLE2 and CL3] and having control—specifically the ability to stop—allows users to explore or confront activities they would not feel able to try in the real world: “you can always turn it off...you’re not going to be halfway round a roller coaster having a panic attack” [PWLE2]; “you can take it off any time” [PWLE3].

People with lived experience of eating disorders suggested VR could also help make therapy more closely related to real life, by making it more engaging and action-based “I find sitting on the couch in the room [in therapy] really tough, I think it’s [VR] something physical to do, a practical thing to do” [PWLE3]. They also suggested that VR might enable therapeutic work to feel more directly connected to real life because it could enable “the therapist [to be] there with you as you’re experiencing those things...rather than...have to remember these situations and then feed them back...that’s a challenge to remember what you’ve actually thought and felt at that moment in time and then be able to share it with a therapist when you’ve got that meeting...three days later” [PWLE2]. Another person with lived experience of eating disorders explained “I’m going to benefit from maybe being in a room with my therapist and having a sort of virtual reality...challenge and her sort of...being able to be there, in the moment...I think it would help me feel like we’ve

had a better understanding of what it actually feels like in that moment” [PWLE1].

Clinicians discussed the possibility of using VR alongside existing treatments “whatever that end goal is I think that it requires picking up on tools that you think are going to work for that particular individual and I just see VR as being a tool”, adding “if it was available you might be kind of picking it off the shelf” [CL3]. Relatedly, they mentioned its potential as a scalable resource, enabling more support than might otherwise be possible in overstretched services: “potentially then, we know that people are getting something additional to what they are currently able to access often in services” [CL2].

Limitations of VR

Some people thought VR headsets might be heavy, uncomfortable, or hard to take off quickly. Some without personal experience of VR were worried about feeling claustrophobic or “panicky” [PWLE2], though this was countered by the experience of others.

Practical concerns about being unable to see one’s surroundings and feeling off-balance were also raised, contributing to fears about feeling unsafe and “vulnerable” [PWLE1 and PWLE2] while using VR; it was felt that individuals’ experiences may increase such feelings. Participants also described potentially feeling self-conscious, a common experience when trying VR in other contexts: “I think you feel like a bit of a dick when you try it on” [PWLE3].

Both people with lived experience of eating disorders and clinicians were concerned that clinicians might not feel confident about using VR technology, and one person with lived experience of eating disorders also suggested VR was “not for everyone”: “I wouldn’t naturally be very interested in VR to be honest and I think it’s maybe for people who are younger than me” [PWLE3].

Participants also talked about technical limitations relating to the suitability of VR in treating eating disorders. Concerns included the quality of graphics, and that VR may be limited to visual and sound worlds, which would not be able to capture the physical sensations involved in experiencing and recovering from an eating disorder: “when I went through recovery...it was physically existing in a bigger body...like the physical sensation of inhabiting a bigger body...I’m not sure that VR could address” [PWLE1]; “it’s kind of bingeing and then not eating anything, it’s that sense of hunger, like you can’t replicate that with VR” [PWLE1]; “for me there’s an additionality of thinking about smells or sounds” [CL3].

Some clinicians discussed the idea that VR not being real might be unhelpful because it could facilitate avoidance of real life: “fuelling more the idea that we can be this virtual reality person that’s not ourself, because we don’t like ourself” [CL1], or avoidance of treatment: “I think with an eating disorder there’s always this kind of temptation to step away, isn’t there? And actually there is a real need to just get on in there and do it [the

treatment] right away” [CL2]. However, clinicians also described this viewpoint as in “tension” with a recognition of the idea that VR could be used as an intermediate step or “tool” for people who are not yet ready to try things out in real life: “[VR] feels more accessible and then, they feel more kind of empowered and strengthened taking it forwards in the real situations” [CL2].

People with lived experience of eating disorders raised the concern that the fact that it is not real might make VR easier to dismiss: “I might be inclined to think, well that was just in VR, in real life it would be totally different” [PWLE1]; “I think it must be really difficult to...apply it because you think well that wasn’t real” [PWLE2].

One person with lived experience of eating disorders also raised the idea of VR being a fad and the possibility that it could be an expensive distraction from the need to train more therapists

Potential VR Interventions

Participants made a wide range of suggestions for potential VR interventions to help and treat people with eating disorders. They agreed treatments would need to vary for each individual: “ultimately it has to have meaning to the person you’re working with” [CL1]; “no pun intended, one size definitely won’t fit all” [PWLE1]. However, suggestions could be grouped according to the type of intervention.

Practicing Everyday Challenges

One common type of intervention discussed by participants was the idea of using VR to “sort of put yourself in that [challenging] situation as an in-between step before you end up doing it” [PWLE2]; or “practicing helpful behaviours or responses to situations...having an opportunity to try out responding in a different way...so...it could feel much easier to access that in the real world” [CL2]. Challenges fell into 3 main groups: food-related scenarios, weight/appearance-related scenarios, and challenging interactions. Examples are presented in [Table 2](#).

Both groups discussed how VR could allow people with eating disorders to practice such challenges in a protected way, to decrease anxiety or “desensitise” [PWLE2] oneself, thus providing an in-between step before going into a real situation “there’s a whole lot of...step-based approaches to end up with sitting in a café having a piece of cake...[in VR] you’re taking away a whole layer of somebody being concerned about the public’s reaction to them” [CL3]. VR might fill an important gap between talking about doing something and actually doing it: “it’s kind of that buffer, that bridge to being exposed to those things in a real world” [PWLE1]; “it could probably lend itself quite well to practising going up to someone and saying, you know, can I have this drink or whatever, like it would be a good sort of in between step, because otherwise...there’s lots of talking and planning around it but there’s nothing in between that can, you know, reduce their anxiety” [CL4].

Table 2. Quotes about challenges and potential VR interventions.

Challenges and specific scenarios	Quotes describing challenges	Quotes relating to the proposed VR intervention
Food-related scenarios		
Cafés	<ul style="list-style-type: none"> going into Costa or whatever and ordering that hot chocolate...those other challenges that are almost kind of like steps before the eating [PWLE2] having to talk to a waiter or...interact in a normal way whilst your brain is feeling anything but normal [PWLE1] 	<ul style="list-style-type: none"> getting used to...where all the cakes are on the counter and not feeling too overwhelmed by that [PWLE2] I will never meet the person who's in this situation as a waiter, therefore I can try saying different stuff and then you can kind of repeat the same situation [PWLE1]
Supermarkets	<ul style="list-style-type: none"> I really struggled with going into a supermarket to pick a sandwich off the shelf...I get paralysed with the indecision and the kind of temptation to look at calorie labels and the knowledge I shouldn't be [PWLE1] I would struggle with not impulsively buying loads of food for binge eating [PWLE3] 	<ul style="list-style-type: none"> making sure like you go down each aisle...when there's like the chocolate aisle or whatever and physically taking one off the shelf, putting it in your basket...trying not to check the calories or seeing other people's responses, actually no one is shouting at you, oh look at the girl, she's got chocolate in her basket...just to get exposure to those sorts of things [PWLE2]
Eating in public	<ul style="list-style-type: none"> eating in front of others...if I'm in work I find that almost impossible because you think everybody's watching you [PWLE2] 	<ul style="list-style-type: none"> the idea of eating a real meal but in an environment created by the VR. With other people around and again that idea of are people going to be watching me...experiencing that a few times will desensitise me to go out and do it [PWLE2]
Portion sizing	<ul style="list-style-type: none"> I don't have a good sense of how much I should be eating or shouldn't be eating [PWLE1] 	<ul style="list-style-type: none"> serve yourself a meal from this thing and then you could then say, okay, the nutrients you're getting from that [PWLE1] you could have a go at dishing yourself up a plate of food...and all of a sudden pull out of the cupboard what somebody might consider to be a normal plate of food and have a conversation [CL3]
Weight/appearance-related scenarios		
Being weighed	<ul style="list-style-type: none"> I'm happy to get on my own scales now...whereas when I was anorexic it was terrible [PWLE3] 	<ul style="list-style-type: none"> having a conversation about how do you feel...looking at those scales being now in your virtual room [PWLE3] perhaps you have an expectation or desire of what you want the number [on the scales] to be and it's not that, or in one scenario it's more than what you expect it to be and how would you feel about that? [PWLE3]
Changing rooms/gyms	<ul style="list-style-type: none"> The environment that I felt was really difficult would be changing rooms...I just feel very self-conscious [PWLE3] 	<ul style="list-style-type: none"> what is it like to go into a gym where everybody is extremely muscular and like how do I feel about that? [PWLE3]
Public places	<ul style="list-style-type: none"> I couldn't walk on the main roads because I thought I was too ugly...I thought...cars...would crash because I was so like shockingly hideous [PWLE3] 	<ul style="list-style-type: none"> you could use VR to kind of emulate that feeling of being in a body and being looked at...the feeling of being observed and how to get through that [PWLE1]
Clothes shopping	<ul style="list-style-type: none"> one of the biggest limitations if you go clothes shopping and obviously there's great big mirrors everywhere... [PWLE2] 	<ul style="list-style-type: none"> with the eating disorder maybe people can wear certain types of clothes or like baggier clothes and actually even trying on like different styles and realising what you might like or what you might like to experiment...kind of finding your own identity slightly more [PWLE2]

Challenges and specific scenarios	Quotes describing challenges	Quotes relating to the proposed VR intervention
Interactions		
Unhelpful comments	<ul style="list-style-type: none"> I find it really hard to know how to respond...where people are talking about say their own weight or their own eating...or...commenting on my weight or my eating [PWLE1] when they go back to school...what they're going to say [about why they've been away]...we tend not to discharge anyone until they've got a plan around that because that feels so difficult for them [CL4] 	<ul style="list-style-type: none"> having your therapist there with you going look, okay, so they've said that that's made me think that what, yeah, how do I work this through [PWLE1]
Asking for help	<ul style="list-style-type: none"> for me, asking for help was really, really, hard [PWLE3] 	<ul style="list-style-type: none"> if we had a virtual reality scenario where I go and they don't give a great response...I can practise how I'm going to respond to that...it could be about easy steps, like level one, you ask for help and somebody does like whatever...and then other situations where it's more difficult...or more confrontational [PWLE3]
Practice skills	— ^a	<ul style="list-style-type: none"> a virtual environment to practise...skills that they have in DBT [dialectical behaviour therapy] would have been great [PWLE3] practice anything in terms of like life skills...I think mostly like communicating within a family...practising for what you want [CL4]

^aNot available.

Both groups also suggested that VR could be used to try out these situations at different levels of difficulty. For example, other avatars in a VR setting could be used to make challenges easier: “maybe you can have someone in the queue before you ordering that and kind of normalising that” [PWLE2], and situations could also be made increasingly challenging: “graded exposure of challenge...depending on what the fear is, is it talking to other people, is it asking for food, is it having the food in front of you. Like any of those number of things you could recreate in virtual reality” [CL4].

VR could also enable discussion about in-the-moment thoughts and feelings about being in a feared situation, in a way that would be more immediate than talking retrospectively in a therapy session: “going as a VR to a restaurant and then you're talking about, how is it making you feel, the fact the person is eating...might be a useful tool” [CL1]; “you could look at a menu and in the session you can kind of go, okay, what's going through your head and you do it as a CBT [cognitive behavioural therapy] thing” [PWLE1]; “being able to expose yourself to kind of challenging situations like that and being able to talk through what your instant thoughts are and then I guess rationalise them a bit more could be helpful” [PWLE2].

Most people with lived experience of eating disorders and clinicians agreed that this could be useful, though a clinician raised a concern: “is it something that would mean they [patients] could practice it and then [be able to do it] or would [it contribute to feeling that] everything has to be done perfect?” [CL4].

Attention

Several people with lived experience of eating disorders described how their attention was affected by their eating disorder, causing them to fixate when in public on, for example, people with particular body types, or food outlets: “it feels very bizarre to me now but like, I remember walking down the high street and it was like I had a zoom cam in my head, like spot the skinniest person in the street, and then I would focus on them all the time and then compare myself to them” [PWLE1].

They suggested VR could be used to help individuals recognize what they were attending to: “I don't know if you can like eyetrack people over the VR” [PWLE2]; “it would be a really useful tool to kind of just confirm that bias” [PWLE2]. Building on this, they suggested VR might then be used to retrain attention: “actually if they're saying...we've just noticed you're looking at this, how about looking at those” [PWLE2]; “it could be a good way of getting rid of those biases and try to see things in a more kind of healthy and realistic way” [PWLE2].

Representing the Body

Body representation was discussed in terms of whether it could be a therapeutic intervention. The suggestions, why they were felt to be potentially helpful, and supporting quotes are presented in Table 3. The ideas comprised representing the body in an abstract way, having a third-person perspective of one's body, or a third-person perspective of one's body at different weights, and comparing self-generated versions of own body with those generated by the clinician. The area was agreed to be complex, with even the act of choosing how one's body should be

represented giving scope for therapeutic discussion around why someone wanted to be represented in a particular way: “if you allowed somebody to choose say their avatar...to get different conversations about the whys and what fors of choice...how do they think somebody would perceive the avatar and why” [CL3].

Table 3. Quotes relating to how representing the body could be therapeutic.

Representation of the body and how it might help	Illustrative data
Abstract/exploratory representation of body	
<ul style="list-style-type: none"> Reduce the importance of shape and size in self-evaluation 	<ul style="list-style-type: none"> loosen up some of the fixed ideas about your body...lessen the importance of how you view your body [PWLE3] what I looked like...was so central to maintaining anorexia that if there was something that could have helped me shake that up or reconceptualise that, that would have been great...if you could represent yourself, like maybe that's a physical thing or maybe that's also like I want to be courageous or I want to be strong or...I want to climb a mountain [PWLE3]
Third-person perspective of own body	
<ul style="list-style-type: none"> Understand the severity of the illness 	<ul style="list-style-type: none"> if I could have seen myself from the perspective of another in the past I would have been shocked...about how unwell I looked [PWLE3] I had moments [when unwell with anorexia nervosa] of like stepping out of myself and being, my goodness, I look really unwell, whereas most of the time I thought I was overweight [PWLE3]
<ul style="list-style-type: none"> Change attitude to own body and reduce avoidance 	<ul style="list-style-type: none"> practice the sorts of more positive self-talk...to override some of those really powerful negative comments that come up...but then...being able to step away from it quite easily when it feels too much...A lot of people go through life and just kind of avoid looking at their image...and actually, it's more helpful to be able to look at yourself...focusing on the things that you do like about your body and challenging your ideas about the bits you don't like [CL2]
Third-person perspective of own body at different weights	
<ul style="list-style-type: none"> Reduce anxiety about planned weight restoration 	<ul style="list-style-type: none"> seeing yourself as a bigger weight as a kind of like exposure therapy so you can kind of get your head around what that might look like. [PWLE1] ...it would be a good thing for them to see...and...explore...what they see and how they feel about that [planned weight increase] [CL4]
<ul style="list-style-type: none"> Reduce anxiety around small fluctuations in weight 	<ul style="list-style-type: none"> nowadays [in recovery]...I'd find that quite useful actually...it would be interesting to see...this is what you look like with or without like a small weight increment and you can't tell the difference [PWLE1]
<ul style="list-style-type: none"> Seeing that other people do not react as feared 	<ul style="list-style-type: none"> you could see other people's responses to you at that normal weight and just witness that actually people aren't going, oh my gosh, that's huge, or people aren't responding at all [PWLE2]
Compare self-generated with VR-generated image	
<ul style="list-style-type: none"> Allow comparisons and discussions 	<ul style="list-style-type: none"> you could ask somebody...to come up with their own image about what they look like and then overlay the comparison, if somebody can tolerate that...I think those are...helpful possible conversations to have [CL3]

Various caveats were expressed. These included the idea that some interventions might not be useful for everyone: “other people might potentially find it triggering” [PWLE3], and that it may be unhelpful to focus too much on appearance “the way we look is just a small part of who we are, and there's probably other things we want things to be doing alongside” [CL2].

Manipulating the weight of the body representation was particularly controversial. Some people with lived experience of eating disorders felt it would not be helpful, that they would not want to experience it, or that it may be counterproductive. There were concerns from both clinicians and people with lived experience of eating disorders that it might lead to increased rumination about body size, or lead to further disordered eating behaviors or weight loss: “it really could have

triggered...restricting behaviours if it really kind of distressed me...kind of almost like an anxiety thing like just the fear of kind of knowing what you look like” [PWLE2]; “[if] you don't like what you see and then you go, wow, I don't want that and then it's going to push you down the other way so it's a bit of a risk” [PWLE1].

Another concern was that images of self at a healthier weight might encourage a focus on specific body parts rather than on the overall appearance of looking “well”: “they might just be focussing on, ‘Oh god, there's no thigh gap’ you know...would they be able to see the glowing skin and the healthy hair..?” [CL2]. Some clinicians also wondered if very unwell patients would be able to make use of it, highlighting that it would need to be used in an appropriate and timely fashion: “for somebody

very much in the grip of anorexia...I can imagine you'd have conversations, 'Well, the computer's wrong'" [CL3]. Another question was how it would be possible to know what one's body would look like at a different weight: "you can't really predict what that would be like just through like a computer algorithm" [PWLE1].

There was general agreement that therapeutic work around body representation would be better done with the support of a therapist: "I would only want to do it with a therapist that I trusted rather than having the option to look at it at home" [PWLE2]. This was partly because people wanted to be supported through the process, and partly because they felt it would be useful for someone else to be in control as repeatedly checking might be unhelpful "like controlling the scales and not going on the scales as often as you might otherwise." [PWLE2].

Clinicians also felt that such an intervention would need to be used at the right time in relation to motivation and recovery: "someone that was coming in in a different mindset and...they really did want to change...then yes, maybe it would work" [CL1], and that if used it should not be a drawn out intervention but "quite time-limited or focused bit of work" [CL2].

Representing the Eating Disorder

One person with lived experience of eating disorders had a previous experience of using an art program in VR as a means of illustrating his eating disorder. In it, he "was trying to simulate what happens when you start eating again after starvation...it was also quite good at communicating to other people as well" [PWLE3]. He explained "I'd lived that in difficult feelings and difficult behaviours and stuff but I hadn't been able to communicate it in words and I think that communicating it visually and using space and colour...was really powerful and therapeutic." Part of what had been helpful was "you have the paintbrush and you are in charge, you have agency...it met some of those core needs about agency" [PWLE3]. Another person with lived experience of eating disorders agreed "this is about creativity and doing something different in the space...I think it would really appeal to me" [PWLE3]. One clinician also suggested VR could be used to help patients separate their eating disorder from their idea of themselves, for example, by creating a representation of the eating disorder in the virtual world: "that classic anorexia externalisation process of having anorexia in the room with you...There might be a place for that as well as the young person" [CL3].

Psychoeducation

People with lived experience of eating disorders described their family members, friends, and clinicians finding it hard to understand what they were experiencing: "so much of the pain in the heart of having an eating disorder is people around you just not understanding" [PWLE1]. They suggested that VR training could help others to understand eating disorders better: "to train therapists or charity volunteers or GPs or family to...get that kind of level of understanding and empathy" [PWLE1]. For example, VR could be used to "show the messages, pinging and pinging with all the influencing thoughts that

we get...the fact that you're focusing on you know skinny people, calorie labels, smells..." [PWLE1].

Clinicians agreed VR could be used to "increase family members' understanding" [CL4] and "help them step into a different position" [CL3]. One clinician suggested VR could be used as part of family-based therapy, to coach parents in skills to support their child so that "the parent can go in more likely to get it right, I guess having had a bit of practice with that beforehand" [CL2]. However, they also wondered what might be lost through the young person not witnessing their parent being coached as would be her normal practice "when the young person sees the parent being coached...sometimes that's really helpful because they know...it's not just coming from the parent...it's the professionals."

One person with lived experience of eating disorders suggested that VR could be used to make learning about eating disorders more engaging for those with the illness too: "I think it would be a really good learning module...actually I find concentrating very difficult so to make learning fun and engaging and dynamic" [PWLE3].

Enabling Therapeutic Conversations With Oneself

People with lived experience of eating disorders raised the possibility of VR enabling them to see themselves from an external perspective which will allow them to support themselves better. It could be a "learning opportunity for you to impart some wisdom so could you kind of visualise, like create yourself, you know, is it that kind of shit that they say...would you say this to other people, what you're saying to yourself" [PWLE3].

Practicalities of Delivering VR Therapy

Overview of Opinions

Participants highlighted practical considerations around the delivery of VR therapy, which would vary according to the precise nature of the intervention. Supportive data for this section are available as [Multimedia Appendix 6](#).

Setting

Opinion was divided as to whether people would rather use VR interventions at home or in the clinic. Arguments in favor of the home environment centered around it being less stressful, especially because one would not need to worry about being observed. However, others preferred the idea of a clinic setting because they felt that a potentially difficult or distressing VR experience could intrude on the safety associated with home, and some questioned whether they would use VR if left to do so independently.

Therapist Presence

Many participants in both groups would want therapist involvement in or alongside any VR, with people with lived experience of eating disorders highlighting that they would need to know and trust their clinician. Others suggested that the therapist's input could be intermittent, with VR providing additional support, for example, between or alongside other therapeutic work.

Timing

The best timing for a VR intervention was agreed to be important, complex, and dependent on the nature of the intervention. Some felt that people with eating disorders may not be able to make use of it if they were significantly underweight or not eating, while others suggested it might be useful for people who were very underweight as it might help to manage high levels of anxiety in relation to beginning treatment. Others felt that VR interventions could be useful at any point, and highlighted that the severity of eating disorder symptoms is not always related to weight. Several participants in both groups raised the patient's current motivation for recovery as important, feeling that this might be the most important factor in whether people would engage with and potentially benefit from VR-based treatments.

Discussion

Principal Findings

Both people with lived experience of eating disorders and clinicians with experience in treating eating disorders were in general positive about the possible future use of VR in eating disorders treatment. They generated a wide range of ideas as to how VR could be used, including to practice challenging situations, retrain attention, represent the eating disorder, for psychoeducation, and to enable therapeutic conversations with oneself. They discussed the complexity of how to represent people's bodies in a VR setting and ways in which this could be done safely and potentially therapeutically. Clinicians and people with lived experience of eating disorders independently suggested similar uses for VR, and the coding framework initially developed for the focus groups with people with lived experience of eating disorders fitted well with data obtained from clinicians.

To our knowledge, this is the first study to explore the views of people with lived experience of eating disorders and clinicians about how VR could be used in the treatment of eating disorders. The focus groups and interviews were extremely rich in detail and explored many ideas in substantial depth. Focus groups included people with several different eating disorder diagnoses, including some with experience of more than 1 diagnosis, and both men and women. We also interviewed clinicians (1 man and 3 women) from a range of professional backgrounds and with varying amounts of professional experience.

Participants highlighted some concerns about the limitations of what is possible in VR, particularly around physical sensations and the sense of smell. In fact, haptics can enable participants to experience physical sensations in a VR setting [9], and it is possible to add an olfactory display to VR to allow the user to manipulate objects in VR and have an experience of smelling them [22].

Strengths and Limitations

Although the study was small scale, we adopted a rigorous approach to data collection and analysis. Credibility was enhanced by the inclusion of 2 sample groups recruited nationally and using multiple sampling strategies to maximize variety in the perspectives obtained. Purposive sampling was

used to ensure that perspectives from men were also included, thus increasing the transferability of the findings. Data analysis was carried out with triangulation between 3 researchers, each with differing backgrounds, and 1 of whom was not involved in data collection. To ensure dependability, the researchers performed independent coding and checking across both sample groups and discussed discrepancies in interpretation to arrive at a comprehensive coding schema that could be applied consistently to the data.

However, we identify the following limitations in the study. First, transferability is limited in relation to ethnicity because both our people with lived experience of eating disorders and clinician samples were limited to people who described their ethnicity as White. This was due to difficulties in recruiting people from other ethnic groups in the time available. It would be useful to expand this work to people from different ethnic groups, and with different cultural backgrounds, in the future, to open up conversations around different cultural experiences of eating disorders and VR. Second, the number of clinicians included was small, again as a result of time limitations. Their input was valuable and is novel in this type of work but it would be useful for future studies to include more clinicians. Third, it is likely that the self-selection among individuals offering to participate may have led to us recruiting participants who were more likely to be positive and enthusiastic about the potential adoption of VR. Lastly, it is possible that findings would have been different had we held interviews instead of focus groups with people with lived experience of eating disorders, and focus groups instead of interviews with clinicians. It is possible that this variation in methodologies meant we collected slightly different data from the 2 sample groups because of the format available to them in which to respond. For example, clinicians' views may have been shaped if they had had the opportunity to interact and reflect with colleagues in situ, and people with lived experience of eating disorders may have been less able to draw on personal narratives in a group setting. Ideally, further research could triangulate these 2 methods of data collection using a mix of the 2 approaches in both sample groups. However, it is notable that the focus groups were small, and we observed individual participants talking in-depth, and also that there was a strong overlap and consistency in the content of themes obtained from the 2 sample groups.

Comparison With Prior Work

Previous work has described a case report of a person with lived experience of eating disorders in the context of her trying VR exposure therapy in which she ate "forbidden" foods [23]. The participant described that she initially perceived the foods as too unhealthy to eat even in a virtual setting, and that she was then able to use the VR environment to practice eating feared foods [23]. However, we have been unable to find previous research which has reported qualitative research findings alongside other results in preliminary trials of VR interventions for eating disorders. We have also been unable to find other qualitative studies exploring the views of people with lived experience of eating disorders around how VR could potentially be used in treating eating disorders, despite the importance of this for ensuring that new interventions are acceptable and

therefore have the potential to be effective in treating eating disorders.

There is also little research on the views of health care professionals on the potential use of VR in treating eating disorders. One survey of practicing cognitive behavioral therapists found that 45% agreed VR could be used for eating disorders (rising to 61% among those with clinical experience of treating people with eating disorders) [24]. They agreed with statements around VR enabling exposure to be tailored to the individual, increasing a sense of control, and making exposure less stressful, and shared concerns we found in our study about whether results would translate into the real world and the ability to use a new technology [24].

Early qualitative work in other areas of VR development for health-related use has found some similar general themes, particularly around the idea of VR as being novel and enjoyable [25,26]. When health care professionals are asked about potential applications for VR, they have many ideas [26].

Some qualitative work has explored the experience of people with other mental health conditions while undergoing VR interventions. These report several themes in common with our findings, such as the VR environment feeling “easier than the real thing” (p. 9) [27] or a good place to practice situations “so you cannot make a fool of yourself” (p. 4) [27]. Relatedly, they describe the potential usefulness of VR in reducing anxiety [28] and building confidence [27,28]. Caveats are also consistent, particularly the concern that it might not be for everyone, and

that benefits might not translate out of a VR environment [27]. Participants were also keen to highlight that the use of VR would need to be supported by someone with whom the patient had a trusting relationship [28].

Implications for Research and Practice

Both people with lived experience of eating disorders and clinicians in our study expressed interest and enthusiasm in the development of interventions using VR to supplement and improve the treatment of eating disorders. This work has highlighted a number of possible interventions that could be developed using VR, including psychoeducation, experiencing challenging situations, attention retraining, and seeking to make therapeutic use of the different ways VR enables one to experience one’s own body. We recommend that such interventions are co-designed with people with personal experience of eating disorders, to maximize their usefulness for this group and reduce the risk of unintended harms. Such novel interventions will subsequently require rigorous evaluation in the form of clinical trials to test their efficacy.

Conclusions

People with personal experience of eating disorders and clinicians who are experienced in their treatment both see many potential roles for VR-based interventions in their treatment, although they are also clear that there is a need for caution and ongoing co-design in their development, particularly around how bodies are represented in a VR setting.

Acknowledgments

We thank all participants for taking part in this research. This work was supported by the Bristol BRC and Brigstow Institute Ideas Exchange Funding. LB is partly funded by the National Institute for Health and Care Research Applied Research Collaboration West (NIHR ARC West). HB is funded by an NIHR Advanced Fellowship (grant 302271).

Data Availability

Data are available to bona fide researchers on request via the University of Bristol Research Data Storage Facility (deposit doi: 10.5523/bris.lpf0ek7zcnxb26yzhe8a5khhbx).

Authors' Contributions

HB, IPV, LB, and LMT researched the literature and conceived the study. HB, IPV, LB, JB, and LMT were involved in protocol development and gaining ethics approval. HB recruited participants. HB and LB collected the data. MRK, HB, and LB were involved in data analysis. HB wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Screening questions for people with lived experience of eating disorders.

[[DOCX File, 22 KB - xr_v1i1e47382_app1.docx](#)]

Multimedia Appendix 2

Screening questions for clinicians.

[[DOCX File, 22 KB - xr_v1i1e47382_app2.docx](#)]

Multimedia Appendix 3

Topic guide for people with lived experience of eating disorders.

[[DOCX File, 23 KB - xr_vli1e47382_app3.docx](#)]

Multimedia Appendix 4

Topic guide for clinicians.

[[DOCX File, 23 KB - xr_vli1e47382_app4.docx](#)]

Multimedia Appendix 5

Powerpoint images shown to participants.

[[PPTX File, 5103 KB - xr_vli1e47382_app5.pptx](#)]

Multimedia Appendix 6

Practicalities of delivering virtual reality therapy for people with eating disorders.

[[DOCX File, 17 KB - xr_vli1e47382_app6.docx](#)]

References

1. Galmiche M, Déchelotte P, Lambert G, Tavolacci MP. Prevalence of eating disorders over the 2000-2018 period: a systematic literature review. *Am J Clin Nutr* 2019 May 01;109(5):1402-1413 [[FREE Full text](#)] [doi: [10.1093/ajcn/nqy342](https://doi.org/10.1093/ajcn/nqy342)] [Medline: [31051507](https://pubmed.ncbi.nlm.nih.gov/31051507/)]
2. Demmler JC, Brophy ST, Marchant A, John A, Tan JOA. Shining the light on eating disorders, incidence, prognosis and profiling of patients in primary and secondary care: national data linkage study. *Br J Psychiatry* 2020 Feb 01;216(2):105-112 [[FREE Full text](#)] [doi: [10.1192/bjp.2019.153](https://doi.org/10.1192/bjp.2019.153)] [Medline: [31256764](https://pubmed.ncbi.nlm.nih.gov/31256764/)]
3. Zerwas S, Larsen JT, Petersen L, Thornton LM, Quaranta M, Koch SV, et al. Eating disorders, autoimmune, and autoinflammatory disease. *Pediatrics* 2017 Dec;140(6):e20162089 [[FREE Full text](#)] [doi: [10.1542/peds.2016-2089](https://doi.org/10.1542/peds.2016-2089)] [Medline: [29122972](https://pubmed.ncbi.nlm.nih.gov/29122972/)]
4. Hudson JI, Hiripi E, Pope HG, Kessler RC. The prevalence and correlates of eating disorders in the National Comorbidity Survey Replication. *Biol Psychiatry* 2007 Feb 01;61(3):348-358 [[FREE Full text](#)] [doi: [10.1016/j.biopsych.2006.03.040](https://doi.org/10.1016/j.biopsych.2006.03.040)] [Medline: [16815322](https://pubmed.ncbi.nlm.nih.gov/16815322/)]
5. Arcelus J, Mitchell AJ, Wales J, Nielsen S. Mortality rates in patients with anorexia nervosa and other eating disorders. A meta-analysis of 36 studies. *Arch Gen Psychiatry* 2011 Jul 04;68(7):724-731. [doi: [10.1001/archgenpsychiatry.2011.74](https://doi.org/10.1001/archgenpsychiatry.2011.74)] [Medline: [21727255](https://pubmed.ncbi.nlm.nih.gov/21727255/)]
6. Mental health of children and young people in England, 2023 - wave 4 follow up to the 2017 survey. NHS Digital. 2023 Nov 21. URL: <https://digital.nhs.uk/data-and-information/publications/statistical/mental-health-of-children-and-young-people-in-england/2023-wave-4-follow-up/part-5-eating-problems-and-disorders> [accessed 2024-05-02]
7. Eddy KT, Tabri N, Thomas JJ, Murray HB, Keshaviah A, Hastings E, et al. Recovery from anorexia nervosa and bulimia nervosa at 22-year follow-up. *J Clin Psychiatry* 2016 Dec 20;78(02):184-189. [doi: [10.4088/jcp.15m10393](https://doi.org/10.4088/jcp.15m10393)]
8. Khalsa SS, Portnoff LC, McCurdy-McKinnon D, Feusner JD. What happens after treatment? A systematic review of relapse, remission, and recovery in anorexia nervosa. *J Eat Disord* 2017 Jun 14;5(1):20 [[FREE Full text](#)] [doi: [10.1186/s40337-017-0145-3](https://doi.org/10.1186/s40337-017-0145-3)] [Medline: [28630708](https://pubmed.ncbi.nlm.nih.gov/28630708/)]
9. PricewaterhouseCoopers. Seeing is believing: how VR and AR will transform business and the economy globally and in the UAE. PricewaterhouseCoopers. Dubai, UAE: PricewaterhouseCoopers; 2019. URL: <https://www.pwc.com/gx/en/technology/publications/assets/how-virtual-reality-and-augmented-reality.pdf> [accessed 2024-04-25]
10. Freeman D, Haselton P, Freeman J, Spanlang B, Kishore S, Albery E, et al. Automated psychological therapy using immersive virtual reality for treatment of fear of heights: a single-blind, parallel-group, randomised controlled trial. *The Lancet Psychiatry* 2018 Aug;5(8):625-632. [doi: [10.1016/s2215-0366\(18\)30226-8](https://doi.org/10.1016/s2215-0366(18)30226-8)]
11. Miloff A, Lindner P, Dafgård P, Deak S, Garke M, Hamilton W, et al. Automated virtual reality exposure therapy for spider phobia vs. in-vivo one-session treatment: a randomized non-inferiority trial. *Behaviour Research and Therapy* 2019 Jul;118:130-140. [doi: [10.1016/j.brat.2019.04.004](https://doi.org/10.1016/j.brat.2019.04.004)] [Medline: [31075675](https://pubmed.ncbi.nlm.nih.gov/31075675/)]
12. Powers MB, Emmelkamp PM. Virtual reality exposure therapy for anxiety disorders: a meta-analysis. *J Anxiety Disord* 2008 Apr;22(3):561-569. [doi: [10.1016/j.janxdis.2007.04.006](https://doi.org/10.1016/j.janxdis.2007.04.006)] [Medline: [17544252](https://pubmed.ncbi.nlm.nih.gov/17544252/)]
13. Freeman D, Lambe S, Kabir T, Petit A, Rosebrock L, Yu L, et al. Automated virtual reality therapy to treat agoraphobic avoidance and distress in patients with psychosis (gameChange): a multicentre, parallel-group, single-blind, randomised, controlled trial in England with mediation and moderation analyses. *The Lancet Psychiatry* 2022 May;9(5):375-388. [doi: [10.1016/s2215-0366\(22\)00060-8](https://doi.org/10.1016/s2215-0366(22)00060-8)]
14. Low TL, Ho R, Ho C, Tam W. The efficacy of virtual reality in the treatment of binge-purging eating disorders: a meta-analysis. *Eur Eat Disord Rev* 2021 Jan 12;29(1):52-59. [doi: [10.1002/erv.2804](https://doi.org/10.1002/erv.2804)] [Medline: [33180339](https://pubmed.ncbi.nlm.nih.gov/33180339/)]

15. Porras-Garcia B, Serrano-Troncoso E, Carulla-Roig M, Soto-Usera P, Ferrer-Garcia M, Figueras-Puigderrajols N, et al. Virtual reality body exposure therapy for anorexia nervosa. a case report with follow-up results. *Front Psychol* 2020 May 15;11:956 [FREE Full text] [doi: [10.3389/fpsyg.2020.00956](https://doi.org/10.3389/fpsyg.2020.00956)] [Medline: [32499742](https://pubmed.ncbi.nlm.nih.gov/32499742/)]
16. Porras-Garcia B, Ferrer-Garcia M, Serrano-Troncoso E, Carulla-Roig M, Soto-Usera P, Miquel-Nabau H, et al. AN-VR-BE. A randomized controlled trial for reducing fear of gaining weight and other eating disorder symptoms in anorexia nervosa through virtual reality-based body exposure. *J Clin Med* 2021 Feb 10;10(4):682 [FREE Full text] [doi: [10.3390/jcm10040682](https://doi.org/10.3390/jcm10040682)] [Medline: [33578767](https://pubmed.ncbi.nlm.nih.gov/33578767/)]
17. Byrne S, Wade T, Hay P, Touyz S, Fairburn CG, Treasure J, et al. A randomised controlled trial of three psychological treatments for anorexia nervosa. *Psychol Med* 2017 May 29;47(16):2823-2833. [doi: [10.1017/s0033291717001349](https://doi.org/10.1017/s0033291717001349)]
18. Lau R, Stevenson F, Ong BN, Dziedzic K, Eldridge S, Everitt H, et al. Addressing the evidence to practice gap for complex interventions in primary care: a systematic review of reviews protocol. *BMJ Open* 2014 Jun 23;4(6):e005548-e005548 [FREE Full text] [doi: [10.1136/bmjopen-2014-005548](https://doi.org/10.1136/bmjopen-2014-005548)] [Medline: [24958212](https://pubmed.ncbi.nlm.nih.gov/24958212/)]
19. McGinty EE, Eisenberg MD. Mental health treatment gap-the implementation problem as a research problem. *JAMA Psychiatry* 2022 Aug 01;79(8):746-747. [doi: [10.1001/jamapsychiatry.2022.1468](https://doi.org/10.1001/jamapsychiatry.2022.1468)] [Medline: [35704300](https://pubmed.ncbi.nlm.nih.gov/35704300/)]
20. Woolf SH. The meaning of translational research and why it matters. *JAMA* 2008 Jan 09;299(2):211-213. [doi: [10.1001/jama.2007.26](https://doi.org/10.1001/jama.2007.26)] [Medline: [18182604](https://pubmed.ncbi.nlm.nih.gov/18182604/)]
21. Birkhead B, Khalil C, Liu X, Conovitz S, Rizzo A, Danovitch I, et al. Recommendations for methodology of virtual reality clinical trials in health care by an international working group: iterative study. *JMIR Ment Health* 2019 Jan 31;6(1):e11973 [FREE Full text] [doi: [10.2196/11973](https://doi.org/10.2196/11973)] [Medline: [30702436](https://pubmed.ncbi.nlm.nih.gov/30702436/)]
22. Niedenthal S, Fredborg W, Lundén P, Ehrndal M, Olofsson JK. A graspable olfactory display for virtual reality. *International Journal of Human-Computer Studies* 2023 Jan;169:102928. [doi: [10.1016/j.ijhcs.2022.102928](https://doi.org/10.1016/j.ijhcs.2022.102928)]
23. Cardí V, Krug I, Perpiñá C, Mataix - Cols D, Rongero M, Treasure J. The use of a nonimmersive virtual reality programme in anorexia nervosa: a single case - report. *Euro Eating Disorders Rev* 2011 Sep 20;20(3):240-245. [doi: [10.1002/erv.1155](https://doi.org/10.1002/erv.1155)] [Medline: [21932282](https://pubmed.ncbi.nlm.nih.gov/21932282/)]
24. Lindner P, Miloff A, Zetterlund E, Reuterskiöld L, Andersson G, Carlbring P. Attitudes toward and familiarity with virtual reality therapy among practicing cognitive behavior therapists: a cross-sectional survey study in the era of consumer VR platforms. *Front Psychol* 2019 Feb 8;10:176 [FREE Full text] [doi: [10.3389/fpsyg.2019.00176](https://doi.org/10.3389/fpsyg.2019.00176)] [Medline: [30800086](https://pubmed.ncbi.nlm.nih.gov/30800086/)]
25. Farič N, Yorke E, Varnes L, Newby K, Potts HW, Smith L, et al. Younger adolescents' perceptions of physical activity, exergaming, and virtual reality: qualitative intervention development study. *JMIR Serious Games* 2019 Jun 17;7(2):e11960 [FREE Full text] [doi: [10.2196/11960](https://doi.org/10.2196/11960)] [Medline: [31210135](https://pubmed.ncbi.nlm.nih.gov/31210135/)]
26. Saab MM, Landers M, Murphy D, O'Mahony B, Cooke E, O'Driscoll M, et al. Nursing students' views of using virtual reality in healthcare: a qualitative study. *J Clin Nurs* 2022 May 22;31(9-10):1228-1242. [doi: [10.1111/jocn.15978](https://doi.org/10.1111/jocn.15978)] [Medline: [34296483](https://pubmed.ncbi.nlm.nih.gov/34296483/)]
27. Holgersen G, Nordgreen T, Ten Velden Hegelstad W, Bircow Elgen I. Views of young people with psychosis on using virtual reality assisted therapy. A qualitative study. *Early Interv Psychiatry* 2023 Apr 16;17(4):361-367. [doi: [10.1111/eip.13331](https://doi.org/10.1111/eip.13331)] [Medline: [35708166](https://pubmed.ncbi.nlm.nih.gov/35708166/)]
28. Brown P, Waite F, Lambe S, Jones J, Jenner L, Diamond R, et al. Automated virtual reality cognitive therapy (gameChange) in inpatient psychiatric wards: qualitative study of staff and patient views using an implementation framework. *JMIR Form Res* 2022 Apr 12;6(4):e34225 [FREE Full text] [doi: [10.2196/34225](https://doi.org/10.2196/34225)] [Medline: [35412462](https://pubmed.ncbi.nlm.nih.gov/35412462/)]

Abbreviations

VR: virtual reality

Edited by T Leung; submitted 17.03.23; peer-reviewed by YC Wang, A Graham, K Erenli; comments to author 08.02.24; revised version received 28.02.24; accepted 21.04.24; published 14.05.24.

Please cite as:

Bould H, Kennedy MR, Penton-Voak I, Thomas LM, Bird J, Biddle L

Exploring How Virtual Reality Could Be Used to Treat Eating Disorders: Qualitative Study of People With Eating Disorders and Clinicians Who Treat Them

JMIR XR Spatial Comput 2024;1:e47382

URL: <https://xr.jmir.org/2024/1/e47382>

doi: [10.2196/47382](https://doi.org/10.2196/47382)

PMID:

©Helen Bould, Mari-Rose Kennedy, Ian Penton-Voak, Lisa May Thomas, Jon Bird, Lucy Biddle. Originally published in JMIR XR and Spatial Computing (<https://xr.jmir.org>), 14.05.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR XR and Spatial Computing, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Original Paper

Enhancement of Immersive Technology Use in Pediatric Health Care With Accessible, Context-Specific Training: Descriptive Feasibility Study

Brian S K Li^{1,2}, AB; Brendan Fereday³, MEd; Ellen Wang², MD; Samuel Rodriguez², MD; Karin Forssell³, PhD; André N Bollaert⁴, BA; Maria Menendez⁵, MD; Thomas J Caruso², MD, PhD

¹Department of Comparative Literature, Princeton University, Princeton, NJ, United States

²Department of Anesthesiology, Perioperative and Pain Medicine, Stanford University School of Medicine, Palo Alto, CA, United States

³Stanford University Graduate School of Education, Palo Alto, CA, United States

⁴Invincikids, Inc, San Bruno, CA, United States

⁵Stanford Children's Health, Palo Alto, CA, United States

Corresponding Author:

Thomas J Caruso, MD, PhD

Department of Anesthesiology, Perioperative and Pain Medicine

Stanford University School of Medicine

453 Quarry Rd

MC 5663

Palo Alto, CA, 94305

United States

Phone: 1 (650) 723 5728

Email: tjcaruso@stanford.edu

Abstract

Background: Immersive technology provides adjuncts for pediatric care. However, accessibility and inadequate training limit implementation of this technology. Standardized instruction with no-cost software licensing may improve health care professionals' facility with immersive technologies.

Objective: This descriptive feasibility study aimed to examine the applications of immersive technologies in pediatric health care, including virtual reality (VR) and projectors.

Methods: We developed immersive technology instructional guides for pediatric health care. The training guides were created for multiple software content and hardware types across several clinical scenarios. Content was available in print and digital versions. The primary outcome was technology use across sites with no-cost software agreements. The secondary outcome was the specific application types used at a single site, stratified by sessions and minutes. Data were analyzed using descriptive statistics.

Results: Data were collected from 19 licensed sites from January through June 2022. Among the 19 sites, 32% (n=6) used 10 or more VR units. Among the 6 sites that had projectors, half used 5 or more units. The mean minutes of use per month of all sites combined was 2199 (IQR 51-1058). Three sites had more than 10,000 minutes of total use during the 6-month review period. Secondary results indicated that active VR (977 total sessions) and passive projector streaming (1261 total sessions) were the most popular application types by session, while active projector (66,849 total minutes) and passive projector streaming (32,711 total minutes) were the most popular types when stratified by minutes of use. The active VR application with the most minutes of use was an application often used in physical therapy.

Conclusions: Context-specific technological instruction coupled to no-cost licenses may increase access to immersive technology in pediatric health care settings.

(*JMIR XR Spatial Comput* 2024;1:e56447) doi:[10.2196/56447](https://doi.org/10.2196/56447)

KEYWORDS

immersive technology; implementation; adult learning; education; pediatric; accessibility; training; therapeutic; pediatric care; utilization; virtual reality; VR; monitoring; license; development; software; monitoring software

Introduction

Although immersive technologies are rapidly developing, their adoption in health care greatly varies due to differences in access and acceptability. Recent research has supported novel health care applications of immersive technologies such as virtual reality (VR) [1,2]. Differences in user backgrounds, including technological literacy and financial resources, remain access barriers for health care systems, creating a digital divide [3-5]. Although immersive technologies are not yet widely used, the market is growing quickly due to reduced costs and improved technology [6,7].

Despite the abundance of efficacy research of immersive technologies in health care, standardized strategies for effective implementation across multiple hospital settings are lacking. Immersive technologies may be adopted for a variety of clinical uses, including patient education, surgical planning, and rehabilitation [8-10]. VR also has analgesic properties, with distraction, focus-shifting, and skill-building identified as its mechanisms for reduced pain perception [11-15]. Given the opioid epidemic, the analgesic benefits of VR could be widely implemented as another tool to reduce the morbidity related to opioid misuse [16-20].

Andragogic learning theories provide the foundation for the development of tools to train health care professionals on how to best use immersive technologies [18-21]. Effective adult learning is guided by the principles of cognitive load engagement and active learning [21-24]. Adult learning theories suggest that short videos and multimedia presentations are more effective than traditional didactic lectures [25]. Lengthier video trainings have variable effects on long-term retention, whereas shorter, segmented videos improve recall [21,26,27]. The use of multimedia instruction, including web-based content, further engages adult learners [28,29].

Given the benefits of immersive technologies, we sought to integrate immersive technologies in pediatric health care settings with a standardized set of clinical guides coupled with no-cost software licensing. While developing learning materials, we remained cognizant of the recency of immersive technology, factors that influence immersive technology acceptance, and best practices to improve learning outcomes.

The primary aim of this descriptive feasibility study was to measure the utilization rate of immersive technologies in a variety of pediatric health care settings after the implementation of standardized training with no-cost software licenses. The secondary aim was to explore the types of immersive technology applications used at a single institution.

Methods

Context

This study was conducted as part of a research and clinical program at an academic children's hospital (Lucile Packard Children's Hospital Stanford [LPCHS]), focusing on the research, development, and validation of immersive technologies for use in pediatric health care [30]. Physicians who lead the program founded a federal, tax-exempt, nonprofit corporation.

The mission of the nonprofit is to distribute pediatric immersive technology applications to reduce anxiety, support rehabilitation, and promote pain perception reduction. This nonprofit also helps children with harm reduction, healthy choice education, and mental health support. The nonprofit works with researchers and health care professionals (including but not limited to physicians, nurse practitioners, registered nurses, child life specialists, and physical therapists) to create and distribute free software that is fun, nonviolent, non-nauseating, and practical for many clinical settings. In addition to providing no-cost software licenses, the nonprofit provides training to help these professionals embed immersive technology in clinical practice. Data for this study were collected from January through June 2022.

Hardware

VR applications distributed by the nonprofit use both portable hardware, including Oculus Go (Meta, Inc), Oculus Quest/Quest 2 (Meta, Inc), and Pico G2 (ByteDance, Ltd). The nonprofit also distributes projector-based applications that use the Nebula Capsule (Anker Innovations Co), a portable smart projector that displays visuals on a surface secured with a mounting clip [31,32].

Training

The training consisted of a series of instructional videos and step-by-step written instructions, available in print and in digital, web-based format. The nonprofit developed a novel framework for introducing and guiding pediatric patients through VR experiences. This framework contained 5 steps: screen, discuss, empower, coach, and clean (Figure 1). These 5 steps were adapted from adult learning theory to fit a health care context, the specific needs of a pediatric population, and the constraints of immersive technology experiences. The nonprofit designed the intervention to be sensitive to several factors: the cognitive load required of practitioners to learn a new skill in a high-risk environment, the plurality of pediatric patient health care needs and constraints, and the requirement to present immersive technologies to patients in a way that elicited their participation.

First, to remain sensitive to the occupational demands on practitioners' working memories, any intervention would need to respect these demands by the use of a sufficiently scaled information hierarchy. For example, the intervention would need to make only the vital information quickly accessible and only deliver new information as necessary. This was accomplished by creating separate guides according to use case, revealing actionable steps around a broadly applicable framework, and through a nested information hierarchy in the digital intervention materials. We further reduced the cognitive load on practitioners by prescribing as many directives for actions and sentence frames for dialogue as possible without tailoring those prescriptions too narrowly to a specific use case.

Second, the intervention needed to balance ease of accessibility with sufficient nuance to capture diverse patient needs. The content catered to the disparate uses of immersive technologies (ie, physical therapy, distraction from pain or fearful environments, and anesthesia induction), patient characteristics (ie, age, mobility, cognitive ability, level of comfort with VR,

quality of eyesight, body position requirements of certain procedures), and the needs of specific experiences (ie, dialogue prompts, experience-specific movements, level of difficulty).

Third, the intervention was designed to elicit patient engagement. Leveraging self-determination theory, the intervention emphasized agency and choice for patients in terms of their VR experience and the amount of information about the external environment they wanted to receive during the VR experience [33,34]. This was also accomplished by incorporating multiple decision points after receiving new information about the VR experience.

The medium consisted of static digital guides that could be printed or digitally referenced, video guides that demonstrated how to conduct a VR experience with patients with different health care goals in varied contexts, and a hierarchically nested digital library that included all resources in addition to descriptions of each immersive technology and their respective use case (Multimedia Appendix 1). Video guides detailed (1) how to use the equipment, (2) how to present the immersive technology intervention to patients, and (3) how to conduct each immersive experience (Multimedia Appendix 2). The guides were available to all licensed nonprofit users.

Figure 1. Excerpt from a learning guide.



Outcomes and Measures

The primary aim of this study was to measure the utilization rate of immersive technologies at institutions that licensed the software through the authors' nonprofit. The secondary aim was to analyze the use of different types of immersive technology applications at a single institution according to site-specific data. Applications were stratified by VR, projector, active, passive, or training. Use was measured by the number of sessions launched and total number of minutes engaged in an application. These data were not available from the entire cohort due to technological privacy related to the license.

Anonymized data were collected from a mobile device management dashboard (Manage XR). This allowed for the measurement of the type of applications (active vs passive), the length of time for which the application was used, and the number of sessions launched.

Analysis

Descriptive statistics were used to analyze the use of immersive technologies at the index institution (LCPHS) as well as at the sites to which the technologies were distributed. Results are reported as means and IQRs.

Ethical Considerations

The Stanford University Institutional Review Board provided a waiver of the requirement of approval owing to the use of historical data.

Results

Primary Outcome: Institutional Use

The software was licensed to 18 institutions in addition to LPCHS. Institutes were located across all 4 Census Bureau regions of the United States (4 in the Northeast, 4 in the Midwest, 5 in the South, and 3 in the West), in addition to 3 sites in Canada. The majority of users seeking license and training agreements were first-time or novice users. Although most (n=17) sites had fewer than 25 pieces of equipment, site

4 and LPCHS possessed over 50 types of equipment. Go and Quest/Quest 2 were the most commonly used equipment types at 34% (100/297) and 44% (131/297) of equipment totals, respectively (Figure 2). Thirteen sites did not have Nebula projectors available; all 6 sites that did have these projectors had at least the same number of VR devices as Nebula projectors (VR/projector ratio>1).

Equipment was variably used among institutions (Figure 3A-B). The mean of monthly usage was 2199 (IQR 51-1058) minutes across all sites combined (Figure 3A). Sites 4, 10, and LPCHS were notable for substantial use with an average of 3613 (IQR 1443-5202), 18,200 (IQR 15,249-23,293), and 5734 (IQR 4807-7252) monthly minutes, respectively (Figure 3B). Only 3 sites had more than 10,000 minutes of total usage across the review period.

Figure 2. Tye of immersive technology equipment available across sites. LPCHS: Lucile Packard Children’s Hospital Stanford.

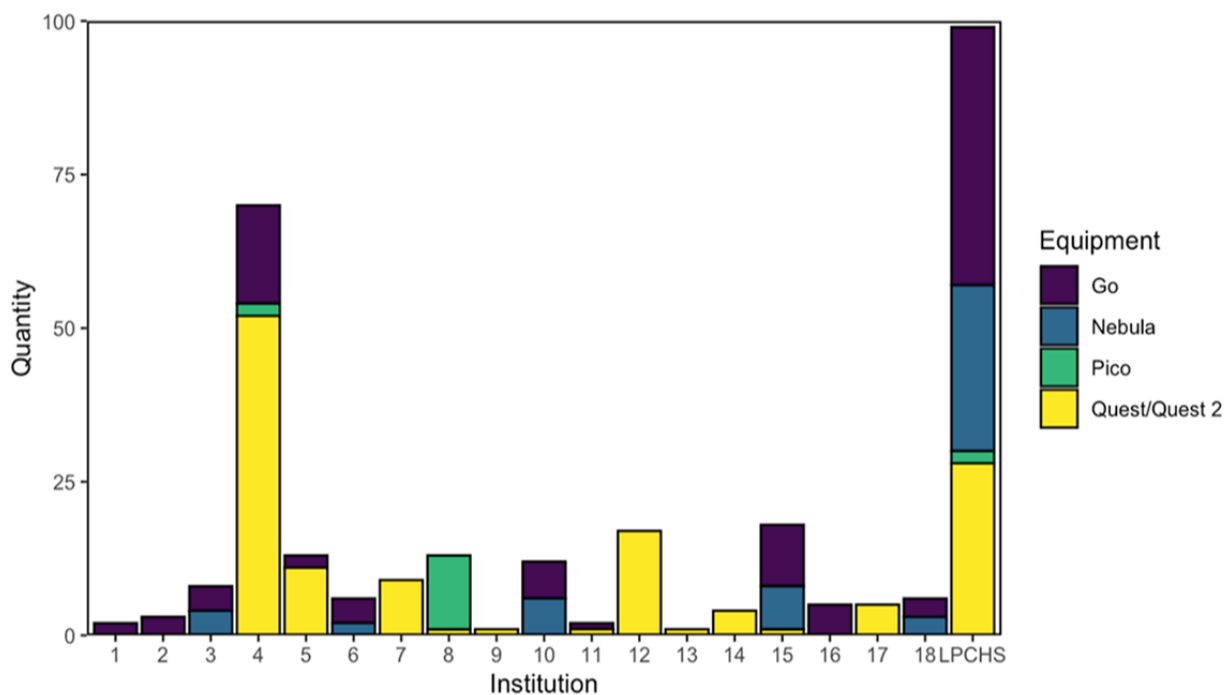
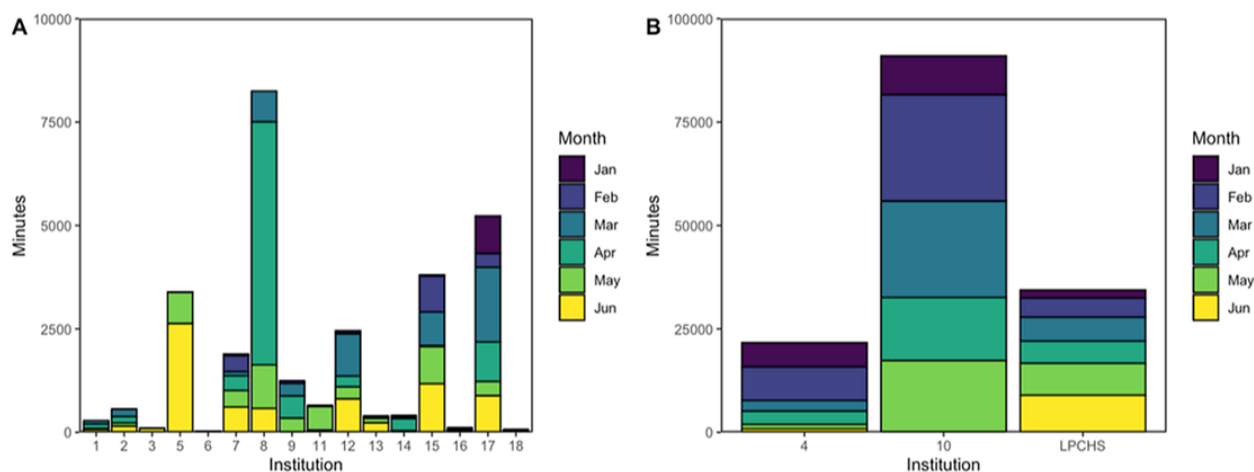


Figure 3. (A) Usage minutes over the review period by month and site for sites with ≤10,000 total minutes of use. (B) Usage minutes over the review period by month and site for sites with >10,000 total minutes of use. LPCHS: Lucile Packard Children’s Hospital Stanford.



Secondary Outcome: Types of Applications Used

The number of sessions and stratified application type increased over the review period at LPCHS (Figure 4). While the level of passive projector use remained consistent, there was an increase in active VR usage. Patients used active VR and passive projector media applications most commonly when analyzed by session count, with 977 and 1261 total sessions, respectively (Figure 4). Patients used active and passive projector streaming most commonly when usage was analyzed by minutes, with 66,849 and 32,711 minutes of use, respectively.

Analysis of specific applications revealed that most sessions of active VR applications were games, including Vacation Simulator (Owlchemy Labs), which accounted for 22%

(212/977) of all active VR sessions. The most-launched passive projector sessions were streaming services such as Netflix, accounting for 57% (720/1261) of all passive projector sessions (Figure 5).

The active VR application with the most minutes of use was an application often used to promote rehabilitation called The Climb 2 (Crytek) with 2815 minutes of use, accounting for 15% (2815/19355) of all active VR minutes. The most frequently used active projector application by minutes was an application designed to facilitate anesthesia induction called Sevo & Desi (Stanford Chariot Program), accounting for 85% (56,860/66,849) of active projector minutes. The most frequently used passive projector application was YouTube, accounting for 55% (18,133/32,711) of passive projector minutes (Figure 6A-B).

Figure 4. Types of applications at Lucile Packard Children’s Hospital Stanford. VR: virtual reality.

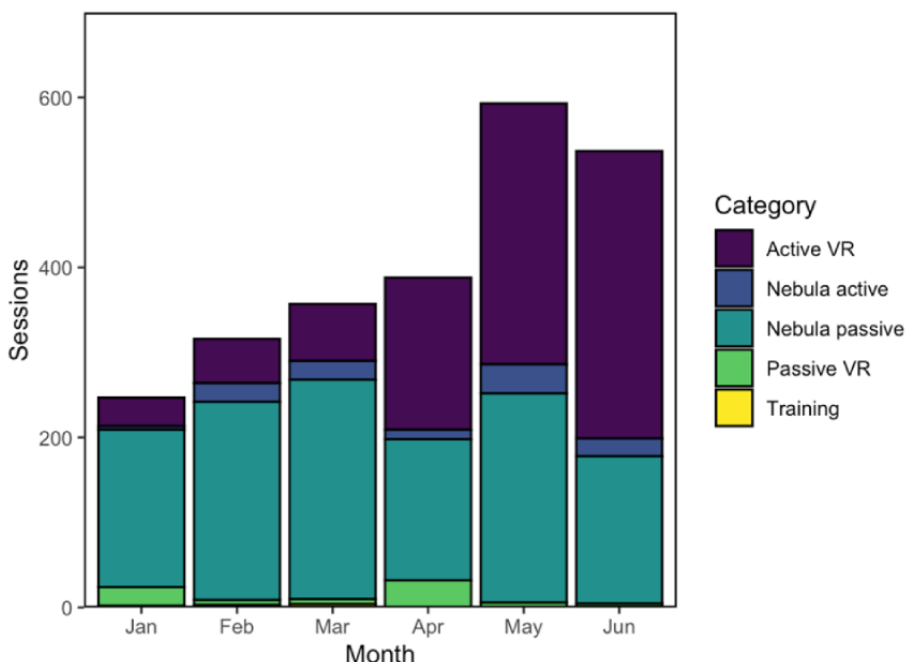


Figure 5. Sessions per application at Lucile Packard Children’s Hospital Stanford. VR: virtual reality.

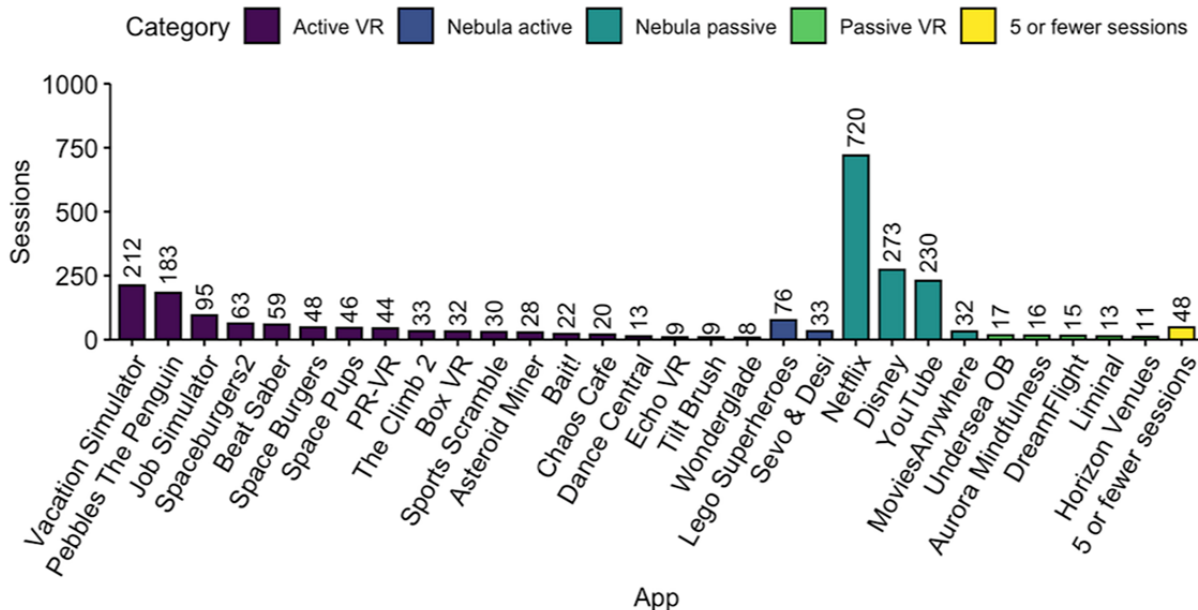
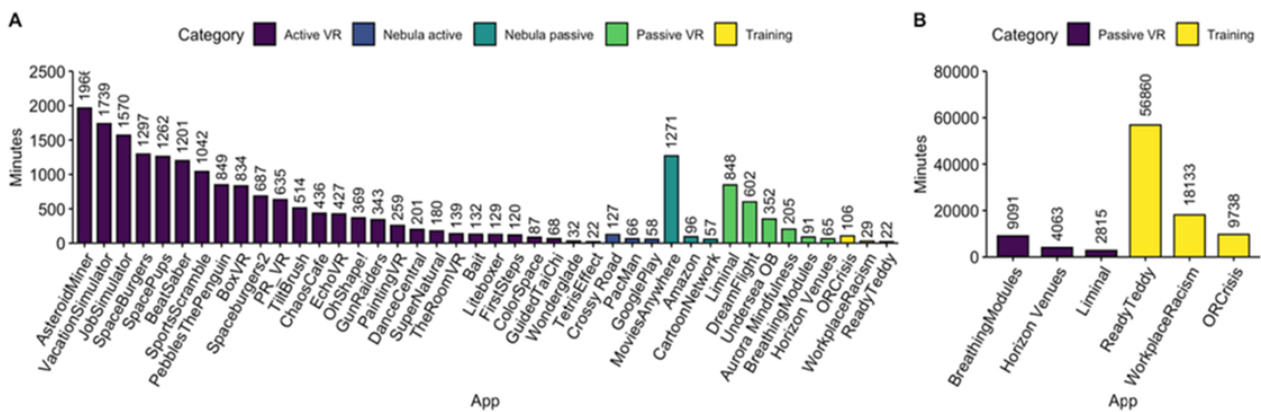


Figure 6. (A) Minutes of use per application with ≤ 2500 total minutes at Lucile Packard Children's Hospital Stanford (LPCHS). (B) Minutes of use per application with >2500 total minutes at LPCHS. VR: virtual reality.



Discussion

Principal Findings

Immersive technologies can be widely disseminated with no-cost licenses and complementary training materials. This study identified variation in the quantity and format of immersive technologies used across each site. The extent of immersive technology use appears to be influenced by the amount of equipment available at each site; most sites had fewer than 25 units of equipment available.

Different hardware is used for different clinical applications in children of different ages. For example, portable VR units may be used for acute distraction at the bedside in older children, whereas projectors are ideal for distraction during patient transport, particularly for younger children. Owing to the different clinical uses among sites, we observed variations in the types of immersive technology units deployed at each site. For example, some institutes only had Go units, such as sites 1, 2, and 16. Many other sites did not have projector units available, limiting streaming options for patients. Most sites were lacking one or more equipment types. Only LPCHS was equipped with all 5 equipment types.

We did not observe any generalizable trends in usage minutes across sites during the 6-month observation period. Rather, monthly usage minutes tended to fluctuate. However, sites with greater monthly minutes tended to experience consistently greater usage across all months than sites with lower usage minutes. At LPCHS, active VR and passive projector media streaming applications were used more often than active projector, passive VR, and training applications, potentially due to the user reception and clinical use setting. Although the data lack information on clinical context, active VR may have been selected by health care professionals when patients needed more immersion and engagement, such as during a stimulating procedure. Technological instruction for hospital staff may have contributed to the increased use of active VR applications at LPCHS, which generally require more training than passive modalities.

Further analyses of the types of software applications used in the hospitals would complement the LPCHS institutional data. Of all application types, we observed the greatest use of active

VR and passive projector content. Whereas active VR and active projector applications generally consisted of a mix of content created by the LPCHS research program and commercially available applications, passive projector applications were more likely to be commercially available streaming services. There is a broad selection of immersive technology content available and further research will be needed to identify the optimal content for different clinical scenarios.

Strengths and Limitations

This study demonstrates the promise for the multi-institutional use of immersive technologies through evidence-based instructional methods. Numerous human factors studies have demonstrated similar outcomes in different domains, including agriculture, industrial organization, household technology use, and online learning [35-38]. This study extends these outcomes by demonstrating the feasibility of the widespread adoption of immersive technology within the pediatric health care setting. Using a teaching model that prioritizes efficient integration and user accessibility may be a key factor to bridge technology research and clinical use. Furthermore, when institutions are provided with technical instructions based on adult learning techniques, adoption may be improved.

This study had several limitations. First, prior to adoption, all users would have reported their familiarity with device use to better quantify the training effectiveness. However, given the primary goal of increasing use and the deleterious effects of surveys on motivation, we opted to not include a preassessment.

Second, privacy regulations and protections on patient information limited our ability to determine the clinical context associated with each instance of immersive technology use. Additionally, outside of LPCHS, the number of sessions and types of applications were not available for analysis due to privacy policies.

Third, while data on patient demographics and specific uses of each application would have increased our understanding of VR utility, the aim of this project was to demonstrate wide-scale use. The hardware and software licenses did not provide access to protected health information to ensure the cyber safety of users. It was outside the scope of this project to have research assistants collect information on patient and use contexts at the wide variety of institutes included. Unlike most VR studies that

demonstrate specific health care uses without attention to practical implementation, this study describes a means toward practical implementation. Despite the lack of an entire cohort of institutional data, the types of applications used at LPCHS provide important information on the natural clinical use of immersive technologies in a pediatric hospital.

Lastly, while we successfully identified and analyzed widespread adoption across sites, we were unable to obtain a staff-level assessment of user sentiments or demonstrate causality between training materials and utilization rates.

Future Directions

This study demonstrates that technological digital instruction can facilitate the use of immersive technology in a wide variety of pediatric health care settings. Such methods have the potential to increase user acceptability and to be adapted to the instructional context. Further research will focus on the efficacy of different educational tools during technology instruction with user-specific feedback. Additional efforts will be made to evaluate factors that influence the acceptability of immersive technologies through the customization of training methods at institutions.

Acknowledgments

The authors recognize the clinical team of the Stanford Chariot Program, Stanford University, Palo Alto, California, for their dedication to using immersive technologies to transform pediatric health care delivery.

Data Availability

The data sets generated and/or analyzed during this study are available from the corresponding author on reasonable request.

Authors' Contributions

EW and TJC conceived, planned, and supervised the study. EW performed the main investigation. All authors contributed to, revised, approved, and are accountable for the final manuscript.

Conflicts of Interest

TJC, SR, KF, and EW are on the board of Invincikids, a nonprofit organization that seeks to distribute immersive technologies to improve pediatric care. They receive no compensation for their roles. ANB is the Executive Director of Invincikids. The Stanford Chariot Program has received philanthropic gifts from Meta, Inc and Magic Leap, Inc. All other authors have no conflicts to declare.

Multimedia Appendix 1

Digital app library materials (excerpt from website).

[[PNG File , 356 KB - xr_v1i1e56447_app1.png](#)]

Multimedia Appendix 2

Virtual reality physical therapy field guide (excerpt from website).

[[MP4 File \(MP4 Video\), 19607 KB - xr_v1i1e56447_app2.mp4](#)]

References

1. Sutherland I. A head-mounted three dimensional display. In: AFIPS '68 (Fall, part I): Proceedings of the December 9-11, 1968, Fall Joint Computer Conference, Part I. New York, NY: Association for Computing Machinery; Dec 1968:757-764.
2. Suh A, Prophet J. The state of immersive technology research: a literature analysis. *Comput Hum Behav* 2018 Sep;86:77-90. [doi: [10.1016/j.chb.2018.04.019](https://doi.org/10.1016/j.chb.2018.04.019)]
3. Lee J, Kim J, Choi JY. The adoption of virtual reality devices: the technology acceptance model integrating enjoyment, social interaction, and strength of the social ties. *Telemat Inform* 2019 Jun;39:37-48. [doi: [10.1016/j.tele.2018.12.006](https://doi.org/10.1016/j.tele.2018.12.006)]
4. Lee LN, Kim MJ, Hwang WJ. Potential of augmented reality and virtual reality technologies to promote wellbeing in older adults. *Appl Sci* 2019 Aug 30;9(17):3556. [doi: [10.3390/app9173556](https://doi.org/10.3390/app9173556)]
5. Seifert A, Reinwand D, Schlomann A. Designing and using digital mental health interventions for older adults: being aware of digital inequality. *Front Psychiatry* 2019;10:568 [FREE Full text] [doi: [10.3389/fpsy.2019.00568](https://doi.org/10.3389/fpsy.2019.00568)] [Medline: [31447716](https://pubmed.ncbi.nlm.nih.gov/31447716/)]
6. Castelvechi D. Low-cost headsets boost virtual reality's lab appeal. *Nature* 2016 May 12;533(7602):153-154. [doi: [10.1038/533153a](https://doi.org/10.1038/533153a)] [Medline: [27172022](https://pubmed.ncbi.nlm.nih.gov/27172022/)]
7. Ebert C. Looking into the future. *IEEE Softw* 2015 Nov;32(6):92-97. [doi: [10.1109/ms.2015.142](https://doi.org/10.1109/ms.2015.142)]
8. Pandrangi VC, Gaston B, Appelbaum NP, Albuquerque FC, Levy MM, Larson RA. The application of virtual reality in patient education. *Ann Vasc Surg* 2019 Aug;59:184-189. [doi: [10.1016/j.avsg.2019.01.015](https://doi.org/10.1016/j.avsg.2019.01.015)] [Medline: [31009725](https://pubmed.ncbi.nlm.nih.gov/31009725/)]

9. Reinschluessel A, Muender T, Salzmann D, Döring T, Malaka R, Weyhe D. Virtual reality for surgical planning - evaluation based on two liver tumor resections. *Front Surg* 2022;9:821060 [FREE Full text] [doi: [10.3389/fsurg.2022.821060](https://doi.org/10.3389/fsurg.2022.821060)] [Medline: [35296126](https://pubmed.ncbi.nlm.nih.gov/35296126/)]
10. Lei C, Sunzi K, Dai F, Liu X, Wang Y, Zhang B, et al. Effects of virtual reality rehabilitation training on gait and balance in patients with Parkinson's disease: a systematic review. *PLoS One* 2019;14(11):e0224819 [FREE Full text] [doi: [10.1371/journal.pone.0224819](https://doi.org/10.1371/journal.pone.0224819)] [Medline: [31697777](https://pubmed.ncbi.nlm.nih.gov/31697777/)]
11. Ahmadpour N, Randall H, Choksi H, Gao A, Vaughan C, Poronnik P. Virtual reality interventions for acute and chronic pain management. *Int J Biochem Cell Biol* 2019 Sep;114:105568. [doi: [10.1016/j.biocel.2019.105568](https://doi.org/10.1016/j.biocel.2019.105568)] [Medline: [31306747](https://pubmed.ncbi.nlm.nih.gov/31306747/)]
12. Triberti S, Repetto C, Riva G. Psychological factors influencing the effectiveness of virtual reality-based analgesia: a systematic review. *Cyberpsychol Behav Soc Netw* 2014 Jun;17(6):335-345. [doi: [10.1089/cyber.2014.0054](https://doi.org/10.1089/cyber.2014.0054)] [Medline: [24892195](https://pubmed.ncbi.nlm.nih.gov/24892195/)]
13. Gold J, Mahrer N. Is virtual reality ready for prime time in the medical space? A randomized control trial of pediatric virtual reality for acute procedural pain management. *J Pediatr Psychol* 2018 Apr 01;43(3):266-275. [doi: [10.1093/jpepsy/jsx129](https://doi.org/10.1093/jpepsy/jsx129)] [Medline: [29053848](https://pubmed.ncbi.nlm.nih.gov/29053848/)]
14. Gupta A, Scott K, Dukewich M. Innovative technology using virtual reality in the treatment of pain: does it reduce pain via distraction, or is there more to it? *Pain Med* 2018 Jan 01;19(1):151-159. [doi: [10.1093/pm/pnx109](https://doi.org/10.1093/pm/pnx109)] [Medline: [29025113](https://pubmed.ncbi.nlm.nih.gov/29025113/)]
15. Birkhead B, Khalil C, Liu X, Conovitz S, Rizzo A, Danovitch I, et al. Recommendations for methodology of virtual reality clinical trials in health care by an international working group: iterative study. *JMIR Ment Health* 2019 Jan 31;6(1):e11973 [FREE Full text] [doi: [10.2196/11973](https://doi.org/10.2196/11973)] [Medline: [30702436](https://pubmed.ncbi.nlm.nih.gov/30702436/)]
16. Pandrangi VC, Shah SN, Bruening JD, Wax MK, Clayburgh D, Andersen PE, et al. Effect of virtual reality on pain management and opioid use among hospitalized patients after head and neck surgery: a randomized clinical trial. *JAMA Otolaryngol Head Neck Surg* 2022 Aug 01;148(8):724-730 [FREE Full text] [doi: [10.1001/jamaoto.2022.1121](https://doi.org/10.1001/jamaoto.2022.1121)] [Medline: [35679057](https://pubmed.ncbi.nlm.nih.gov/35679057/)]
17. Lew D, Bancila L, Wang K, Kim S, Spiegel B, Almario C, et al. S0081 Virtual reality can reduce pain and opioid use in sphincter of Oddi dysfunction (SOD) type III: a prospective pilot study. *Am J Gastroenterol* 2020;115(1):S39-S40. [doi: [10.14309/01.ajg.0000702372.03529.33](https://doi.org/10.14309/01.ajg.0000702372.03529.33)]
18. Alonso Puig M, Alonso-Prieto M, Miró J, Torres-Luna R, Plaza López de Sabando D, Reinoso-Barbero F. The association between pain relief using video games and an increase in vagal tone in children with cancer: analytic observational study with a quasi-experimental pre/posttest methodology. *J Med Internet Res* 2020 Mar 30;22(3):e16013 [FREE Full text] [doi: [10.2196/16013](https://doi.org/10.2196/16013)] [Medline: [32224482](https://pubmed.ncbi.nlm.nih.gov/32224482/)]
19. Firoozabadi R, Elhaddad M, Drever S, Soltani M, Githens M, Kleweno CP, et al. Case Report: Virtual reality analgesia in an opioid sparing orthopedic outpatient clinic setting: a case study. *Front Virtual Real* 2020 Dec;1:553492 [FREE Full text] [doi: [10.3389/frvir.2020.553492](https://doi.org/10.3389/frvir.2020.553492)] [Medline: [33585832](https://pubmed.ncbi.nlm.nih.gov/33585832/)]
20. Smith V, Warty RR, Sursas JA, Payne O, Nair A, Krishnan S, et al. The effectiveness of virtual reality in managing acute pain and anxiety for medical inpatients: systematic review. *J Med Internet Res* 2020 Nov 02;22(11):e17980 [FREE Full text] [doi: [10.2196/17980](https://doi.org/10.2196/17980)] [Medline: [33136055](https://pubmed.ncbi.nlm.nih.gov/33136055/)]
21. Brame CJ. Effective educational videos: principles and guidelines for maximizing student learning from video content. *CBE Life Sci Educ* 2016 Dec;15(4):es6 [FREE Full text] [doi: [10.1187/cbe.16-03-0125](https://doi.org/10.1187/cbe.16-03-0125)] [Medline: [27789532](https://pubmed.ncbi.nlm.nih.gov/27789532/)]
22. Sweller J. Cognitive load during problem solving: effects on learning. *Cogn Sci* 1988 Jun;12(2):257-285. [doi: [10.1016/0364-0213\(88\)90023-7](https://doi.org/10.1016/0364-0213(88)90023-7)]
23. Freeman S, Eddy SL, McDonough M, Smith MK, Okoroafor N, Jordt H, et al. Active learning increases student performance in science, engineering, and mathematics. *Proc Natl Acad Sci U S A* 2014 Jun 10;111(23):8410-8415 [FREE Full text] [doi: [10.1073/pnas.1319030111](https://doi.org/10.1073/pnas.1319030111)] [Medline: [24821756](https://pubmed.ncbi.nlm.nih.gov/24821756/)]
24. Noetel M, Griffith S, Delaney O, Harris NR, Sanders T, Parker P, et al. Multimedia design for learning: an overview of reviews with meta-meta-analysis. *Rev Educ Res* 2021 Oct 23;92(3):413-454. [doi: [10.3102/003465432111052329](https://doi.org/10.3102/003465432111052329)]
25. Caruso TJ, Qian J, Lawrence K, Armstrong-Carter E, Domingue BW. From Socrates to virtual reality: a historical review of learning theories and their influence on the training of anesthesiologists. *J Educ Perioper Med* 2020;22(2):E638 [FREE Full text] [doi: [10.46374/volxxii-issue2-Caruso](https://doi.org/10.46374/volxxii-issue2-Caruso)] [Medline: [32939366](https://pubmed.ncbi.nlm.nih.gov/32939366/)]
26. Guo P, Kim J, Rubin R. How video production affects student engagement: an empirical study of MOOC videos. In: *L@S '14: Proceedings of the first ACM Conference on Learning @ Scale Conference*. New York, NY: Association for Computing Machinery; Mar 2014:41-50.
27. Stockwell BR, Stockwell MS, Cennamo M, Jiang E. Blended learning improves science education. *Cell* 2015 Aug 27;162(5):933-936 [FREE Full text] [doi: [10.1016/j.cell.2015.08.009](https://doi.org/10.1016/j.cell.2015.08.009)] [Medline: [26317458](https://pubmed.ncbi.nlm.nih.gov/26317458/)]
28. Çeken B, Taşkın N. Multimedia learning principles in different learning environments: a systematic review. *Smart Learn Environ* 2022 Apr 13;9(1):19. [doi: [10.1186/s40561-022-00200-2](https://doi.org/10.1186/s40561-022-00200-2)]
29. Abdul AA, Ibrahim M, Jono MNHH, Asarani NAM. Incorporating instructional design and adult learning theory in the e-content development of an interactive multimedia course. 2014 Presented at: 2014 International Symposium on Technology Management and Emerging Technologies; May 27-29, 2014; Bandung, Indonesia. [doi: [10.1109/istmet.2014.6936522](https://doi.org/10.1109/istmet.2014.6936522)]
30. Stanford CHARIOT Program. Stanford University. URL: <http://chariot.stanford.edu/> [accessed 2023-01-06]

31. Richey A, Khoury M, Segovia N, Hastings KG, Caruso TJ, Frick S, et al. Use of Bedside Entertainment and Relaxation Theater (BERT) to reduce fear and anxiety associated with outpatient procedures in pediatric orthopaedics. *J Pediatr Orthop* 2022 Jan 01;42(1):30-34. [doi: [10.1097/BPO.0000000000002005](https://doi.org/10.1097/BPO.0000000000002005)] [Medline: [34739431](https://pubmed.ncbi.nlm.nih.gov/34739431/)]
32. Rodriguez ST, Jang O, Hernandez JM, George AJ, Caruso TJ, Simons LE. Varying screen size for passive video distraction during induction of anesthesia in low-risk children: a pilot randomized controlled trial. *Paediatr Anaesth* 2019 Jun 14;29(6):648-655. [doi: [10.1111/pan.13636](https://doi.org/10.1111/pan.13636)] [Medline: [30916447](https://pubmed.ncbi.nlm.nih.gov/30916447/)]
33. Yoo J, Lee S, Ohu EA. A cross-cultural analysis of VR gaming psychological needs and motivations: a self-determination theory approach. *Manag Sport Leis* 2022 Mar 03;29(3):392-412. [doi: [10.1080/23750472.2022.2046490](https://doi.org/10.1080/23750472.2022.2046490)]
34. Huang Y, Backman SJ, Backman KF, McGuire FA, Moore D. An investigation of motivation and experience in virtual learning environments: a self-determination theory. *Educ Inf Technol* 2018 Aug 18;24(1):591-611. [doi: [10.1007/s10639-018-9784-5](https://doi.org/10.1007/s10639-018-9784-5)]
35. Damba OT, Ansah IGK, Donkoh SA, Alhassan A, Mullins GR, Yussif K, et al. Effects of technology dissemination approaches on agricultural technology uptake and utilization in Northern Ghana. *Technol Soc* 2020 Aug;62:101294. [doi: [10.1016/j.techsoc.2020.101294](https://doi.org/10.1016/j.techsoc.2020.101294)]
36. Pagano A, Carloni E, Galvani S, Bocconcelli R. The dissemination mechanisms of Industry 4.0 knowledge in traditional industrial districts:evidence from Italy. *Compet Rev* 2020 May 28;31(1):27-53. [doi: [10.1108/cr-12-2019-0160](https://doi.org/10.1108/cr-12-2019-0160)]
37. Mitzner TL, Fausset CB, Boron JB, Adams AE, Dijkstra K, Lee CC, et al. Older adults' training preferences for learning to use technology. *Proc Hum Factors Ergon Soc Annu Meet* 2008 Sep;52(26):2047-2051 [FREE Full text] [doi: [10.1177/154193120805202603](https://doi.org/10.1177/154193120805202603)] [Medline: [25309139](https://pubmed.ncbi.nlm.nih.gov/25309139/)]
38. Fong BYF, Yee HHL, Ng TKC, Law VTS. The use of technology for online learning among older adults in Hong Kong. *Int Rev Educ* 2022 Jul 15;68(3):389-407 [FREE Full text] [doi: [10.1007/s11159-022-09957-7](https://doi.org/10.1007/s11159-022-09957-7)] [Medline: [35855478](https://pubmed.ncbi.nlm.nih.gov/35855478/)]

Abbreviations

LPCHS: Lucile Packard Children's Hospital Stanford

VR: virtual reality

Edited by T Leung; submitted 16.01.24; peer-reviewed by Z Orgil, K Chen; comments to author 16.02.24; revised version received 13.03.24; accepted 15.07.24; published 30.07.24.

Please cite as:

Li BSK, Fereday B, Wang E, Rodriguez S, Forssell K, Bollaert AN, Menendez M, Caruso TJ

Enhancement of Immersive Technology Use in Pediatric Health Care With Accessible, Context-Specific Training: Descriptive Feasibility Study

JMIR XR Spatial Comput 2024;1:e56447

URL: <https://xr.jmir.org/2024/1/e56447>

doi: [10.2196/56447](https://doi.org/10.2196/56447)

PMID:

©Brian S K Li, Brendan Fereday, Ellen Wang, Samuel Rodriguez, Karin Forssell, André N Bollaert, Maria Menendez, Thomas J Caruso. Originally published in *JMIR XR and Spatial Computing* (<https://xr.jmir.org>), 30.07.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in *JMIR XR and Spatial Computing*, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Original Paper

Mobile Phone–Based Personalized and Interactive Augmented Reality Pictorial Health Warnings for Enhancing a Brief Advice Model for Smoking Cessation: Pilot Randomized Controlled Trial

Ziqiu Guo¹, PhD; Yongda Wu^{1,2}, PhD; Man Ping Wang¹, PhD

¹School of Nursing, The University of Hong Kong, Hong Kong, China (Hong Kong)

²Children's Hospital of Eastern Ontario Research Institute, Ottawa, ON, Canada

Corresponding Author:

Yongda Wu, PhD

School of Nursing

The University of Hong Kong

3 Sassoon Road

Pokfulam

Hong Kong

China (Hong Kong)

Phone: 852 39176600

Fax: 852 28726079

Email: yongdang@connect.hku.hk

Abstract

Background: Augmented reality (AR) is a novel modality for promoting smoking cessation (SC). AR-visualized adverse consequences for education and smoking prevention have only been evaluated in nonsmokers in previous studies.

Objective: To assess the feasibility and preliminary effectiveness for SC of AR pictorial health warnings (PHWs) on cigarette packs.

Methods: We conducted a pilot randomized controlled trial in adult daily smokers in communities in Hong Kong. All participants received AWARD (ask, warn, advise, referral, do-it-again) model-guided SC advice, a warning leaflet, and referral to SC services at baseline. Interactive, chat-based SC support comprising regular messages and real-time support was provided to all participants via instant messaging apps (eg, WhatsApp) for 3 months after randomization. Participants in the intervention group additionally received 6 links to the AR PHWs showing the worsening health status of various organs caused by smoking. The level of the AR PHWs was adjustable to smoking behaviors (ie, smoking duration or daily cigarette consumption) to increase interaction. Participants could swipe, drag, or rotate the 3D PHWs to reinforce their impression of the health consequences of smoking. The primary outcome was self-reported past 7-day point-prevalence abstinence (PPA) at 3 months. The acceptability of the AR intervention was assessed by the proportion of participants who had viewed AR PHWs during the intervention. Participants who viewed AR PHWs further evaluated the perceived effect of the AR PHWs on a scale of 0 (not helpful at all) to 10 (very helpful). Intention to treat was used, and the risk ratio (RR) of the intervention effect was estimated by Poisson regression.

Results: From April to November 2021, 80 participants were recruited and randomly assigned to intervention (n=40) and control (n=40) groups. Most participants were male (66/80, 83%) and planned to quit beyond 30 days or were undecided (65/80, 81%). The intervention group had a higher but nonsignificant 7-day PPA (7/40, 18% vs 5/40, 13%; RR 1.40, 95% CI 0.48-4.07) and quit attempts (15/40, 38% vs 11/40, 28%; RR 1.36, 95% CI 0.71-2.60) at 3 months than the control group. In the intervention group, 17 of 40 (43%) participants viewed the AR PHWs. The AR PHWs had modest effects on knowledge of the adverse consequences of smoking on personal health (mean score 3.94, SD 3.52), reducing the frequency of buying cigarettes (mean score 3.29, SD 3.08), increasing the perceived importance of quitting (mean score 3.88, SD 3.50), and making the PHWs more disgusting (mean score 3.41, SD 3.08) and horrible (mean score 3.38, SD 3.05). The 3-month self-reported 7-day PPA was higher in those who ever (vs never) viewed the AR PHWs (5/17, 29% vs 2/23, 9%).

Conclusions: The mobile-based interactive AR PHWs were feasible, and the effectiveness on smoking abstinence warrants further testing.

Trial Registration: ClinicalTrials.gov NCT04830072; <https://clinicaltrials.gov/study/NCT04830072>

KEYWORDS

augmented reality; mobile-based; smoking cessation; brief advice; pictorial health warning; pilot randomized controlled trial

Introduction

Brief advice is effective in promoting smoking cessation (SC) [1-4]. Pictorial and text warnings on adverse smoking consequences are always used to warn smokers about the harms of continued smoking when delivering brief SC advice. Pictorial warnings evoke negative emotions about smoking [5] and increase quit attempts [6] and quit intentions [5]. However, the effects of pictorial and text warnings can be attenuated, since some smokers feel disconnected from the smoking-attributable diseases being shown [7,8]. Enhancing pictorial and text warnings is needed to strengthen their effect on promoting SC. Augmented reality (AR) technology, allowing interaction using vivid 3D visual imaging, has potential for promoting SC and could be promising.

A recent experimental study found that AR-visualized messages about adverse consequences of smoking increased negative emotions toward smoking and willingness to engage in an SC campaign in college students [9]. AR-simulated adverse consequences of smoking (eg, in the lungs) were used in educating nonsmokers about smoking hazards to the human body [10] and dissuading nonsmokers from smoking [11], but the effects were not assessed using a rigorous research design. Recent studies have suggested the potential of AR as a novel modality for conducting cue exposure therapy for SC (ie, extinguishing cue-provoked urges to smoke by exposure to smoking-related cues) since smoking-related AR images were found to have a similar effect on eliciting cue-provoked urges to smoke compared to in vivo smoking cues [12,13]. Our literature review of PubMed (up to September 2023) using the terms “augmented reality” and “smoking cessation” found no study assessing the effect of AR visualization of adverse consequences from smoking on SC. Therefore, a pilot study is needed to assess the feasibility of AR visualization of adverse consequences from smoking for SC to inform a larger-scale, full trial.

Hong Kong has a relatively low smoking prevalence (9.5% in 2021 [14]). However, significant increases in the proportion of smokers without an intention to quit (12.7% to 69%) or past quit attempts (74.4% to 80.4%) were observed from 2009 to 2018 [15]. The penetration of mobile phones in Hong Kong has provided a novel avenue for SC, considering that less-motivated smokers might be receptive to mobile-based intervention [16]. Several studies have shown that widely used mobile instant messaging (IM) apps (eg, WhatsApp, WeChat) are a promising modality for delivering personalized and interactive SC interventions [2,17,18]. Communicating smoking-related adverse consequences with texts or pictures via IM apps was also found to be feasible [18]. These findings suggest that IM apps might be usable to deliver AR for smokers, especially smokers with a lower quit intention who are less willing to download and use additional SC-related apps [19]. Pictorial health warnings (PHWs) on cigarette packs portraying the adverse consequences

of smoking and disseminating messages on quitting are widely and frequently seen by smokers (126 countries and jurisdictions finalized requirements for PHWs by 2021 [20]). Hong Kong introduced PHWs in 2007, and adopted 12 new PHWs with at least 85% coverage of the principal packaging of cigarettes in 2018. In Hong Kong, 88.6% of current smokers reported having seen PHWs in the past 30 days in 2018 [21]. This study used the notion that PHWs are widely viewed by the public on cigarette packaging and developed 6 new, localized, AR-based PHWs (Multimedia Appendix 1). Taking advantage of IM apps, this pilot study aimed to examine the feasibility and preliminary effect of AR PHWs on SC.

Methods

Ethical Considerations

Ethical approval was obtained from the institutional review board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (UW 21-018), and the trial was registered with ClinicalTrials.gov (NCT04830072). Written consent was obtained from all participants after informing them that they had the right to withdraw from the study at any time, and all the information collected was anonymized and was only used for research. After completing each follow-up, all participants were compensated with HK\$ 50 (US\$ 6.40). The Consolidated Standards of Reporting Trials (CONSORT) reporting guidelines and their extension to randomized pilot and feasibility trials were followed [22].

Study Design, Setting, and Participants

We conducted a parallel, 2-arm, pilot randomized controlled trial (RCT) in Hong Kong. From April to November 2021, participants were individually recruited at smoking hot spots (ie, places where smokers linger and smoke) in community sites. Research staff proactively approached smokers using a “foot-in-the-door” technique, which is commonly used in SC trials in the context of smokers with low intention to quit [1,2,23]. Briefly, the research staff initiated a conversation by asking about small and simple questions like their daily cigarette consumption and quit attempts. Those willing to talk were warned about the risk of continuous smoking and advised to quit smoking as early as possible. Smokers who expressed interest in SC were briefly introduced to the trial, screened for eligibility, and invited to join. Eligibility criteria included being Chinese, being a smoker, being aged 18 years or older, smoking at least 1 cigarette daily in the past 30 days, owning a smartphone with IM apps (eg, WhatsApp), and being able to communicate in Chinese. We excluded smokers who were participating in other SC services or projects.

Randomization and Blinding

Participants were individually randomized to intervention or control groups (at a 1:1 ratio) according to a predefined randomization list with permuted block sizes of 2, 4, and 6. The

allocation sequence was generated by a noninvestigator and was concealed from the research staff involved in participant recruitment. To avoid treatment contamination, we only recruited 1 smoker at 1 smoking hot spot at 10-minute intervals. Blinding of participants and the SC advisor who delivered the interventions was not possible. All outcome assessors and statistical analysts were blinded to treatment allocation until the primary analyses were completed.

Interventions

All participants received brief SC advice following the AWARD (ask, warn, advise, referral, do-it-again) model [1-3] and were offered referrals to SC services at baseline. As a widely adopted alternative practice for smokers who are less ready to quit in SC programs [2,24], chat-based SC support was delivered to all participants for 3 months via IM apps (ie, WhatsApp). Guided by motivational interviewing (MI) techniques [25] and the transtheoretical model [26], the chat-based SC support included prescheduled messages and real-time support personalized to the quitting process provided by 1 SC advisor (a registered nurse trained in SC treatments and MI techniques). The 24 prescheduled messages' content and frequency were adjusted according to participants' willingness to quit at baseline based on the transtheoretical model (willing to quit within 30 days/after 30 days or undecided) [26]. For participants willing to quit within 30 days, the messages covered quitting strategies, coping skills, and encouragement. Participants who were not ready to quit within 30 days received messages on motivational advice, benefits of SC, hazards of smoking (and secondhand smoke), and encouragement. At least 1 message was delivered per week to initiate the conversation between participants and the SC advisor. The frequency of the prescheduled messages increased to 2 to 3 per week when approaching the quit date set by the participant. The real-time support was also personalized to participants' inquiries and followed MI techniques to enhance motivation and self-efficacy of quitting. The SC advisor discussed the supporting content with experts in the SC team when necessary.

Six web AR links were integrated into the messages during the chat-based SC support for the intervention group. The AR links were built based on 6 of 12 local PHWs (due to the limited budget; [Multimedia Appendix 1](#)): "smoking takes away my voice," "smoking causes "lung cancer," "smoking causes peripheral vascular disease," "smoking causes impotence," "smoking causes aging," and "smoking offence: fixed penalty HK \$1500." These 6 PHWs were chosen because they were particularly suitable for using 3D animations to show the disease's progression and the increasing cost of smoking. One

AR technology company developed the AR links with the SC experts' continuous comments on the shape and color of the models and necessary changes. All the AR PHWs were designed to increase the participants' awareness of the devastating effects on health of smoking and its ever-growing monetary cost, thereby promoting their engagement in the chat-based SC support. The AR PHWs could be accessed by using the smartphone's camera and the mobile web browser on the 2 most widely adopted mobile operating systems, iOS and Android, without the requirement to download any apps.

The web AR links were opened in a mobile web browser, and the participants were instructed to scan the corresponding PHWs to activate the AR links. Upon successfully scanning the PHWs, they were shown jointly with the corresponding augmented components (ie, 3D PHWs and texts) on the screen. Participants could interact with the augmented components and real-world images at the same time. By default, 30-second 3D animations of the PHWs were played to show the gradually worsening health status of organs (eg, changes in the color and shape of the lungs) because of continuous smoking. The corresponding health status of the organs was displayed in 3D when inputting smoking behaviors (ie, smoking duration or daily cigarette consumption). The 3D PHWs showing the status of the organs could be swiped, dragged, or rotated to be viewed from different angles. Participants could also interact with the 3D PHWs by dragging the horizontal scroll bar to indicate different durations of smoking (or levels of cigarette consumption) to see the changing status of the organs (the AR PHW for "smoking causes peripheral vascular disease" is shown in [Figure 1](#)). The original PHW for "smoking offence: fixed penalty HK \$1500" used images of money to warn smokers that smoking in smoke-free areas has a fine of HK \$1500 (US \$192.30). To keep consistency with other AR PHWs that show changes in organs due to smoking, we redesigned this PHW to show the amount of money spent yearly based on daily cigarette consumption and the average price of a pack of cigarettes (HK\$ 60; US \$7.70) at the time of the study. When activated, the animation showed an increasing amount of money being burned due to smoking. The feeling of holding the 3D PHWs in their hands and viewing them from different angles might remind participants of the corresponding PHWs naturally and intuitively. The SC advisor also encouraged participants to click the links and interact with the AR PHWs and supplemented the information (eg, with corresponding PHWs or a brief introduction) as appropriate. As an alternative way to access the AR PHWs, we provided the PHW images on a separate device (eg, a personal computer running WhatsApp) so that the users could scan the images with their mobile phones.

Figure 1. Example of pictorial health warning (PHW) and corresponding augmented reality PHW.

PHW: smoking causes peripheral vascular disease

Example of 3D animation progress

Input smoking duration

Corresponding status
Scrolling to see the changed status

Measures

At baseline, we collected sociodemographic characteristics (sex, age, education, monthly household income, and employment status), smoking and quitting behaviors (daily cigarette consumption, nicotine dependency level [27], past quit attempts, willingness to quit, and self-efficacy [2]). The nicotine dependency level was measured by the Heaviness of Smoking Index (HSI), which sums up the scores of 2 questions: the number of cigarettes smoked per day and the time to the first cigarette after waking. Total HSI scores of ≤ 2 , 3-4, and 5-6 indicate low, moderate, and high levels of nicotine dependency, respectively. The willingness to quit was measured by asking participants their planned quit date with responses of “within 7 days/30 days/60 days/undecided.”

Telephone follow-ups were conducted at 1 month and 3 months after intervention initiation. The primary outcome was self-reported 7-day point-prevalence abstinence (PPA) at the 3-month follow-up. Secondary outcomes included the 7-day PPA at the 1-month follow-up, smoking reduction by at least 50% of baseline daily cigarette consumption (excluding quitters), and quit attempts (defined by abstinence for at least 24 hours) at the 1- and 3-month follow-ups.

Considering that proactive recruitment and chat-based support via IM apps have shown feasibility in our previous SC studies [1,2,17,28], we calculated the proportion of participants who had viewed the AR PHWs during the intervention to assess the acceptability of the AR intervention component. The proportion was defined as the actual number of participants who reported having ever viewed the AR PHWs at the follow-ups divided by the number of participants in the intervention group. Missing values were treated as “no viewing.” In participants who viewed the AR PHWs, we further evaluated the perceived effect of the AR PHWs on (1) knowing the adverse consequences of smoking on personal health, (2) increasing the perceived importance of quitting, (3) reducing the frequency of buying cigarettes, (4) perceiving PHWs as more disgusting, and (5) perceiving PHWs as more horrible, each on a scale of 0 (not helpful at all) to 10 (very helpful).

Sample Size Calculation

No formal sample size calculation was conducted. The sample size of 80 participants is comparable with previous studies of

virtual reality interventions (ranging from 8-102 [29]) for SC and was deemed sufficient to test the feasibility and estimate the parameters to inform the design of a definitive RCT.

Data Analyses

We compared the primary and secondary outcomes between the 2 groups using Poisson regression with robust variance [30], which yielded risk ratios (RRs) of the intervention effect. The model was further adjusted for imbalanced baseline characteristics (ie, education) as a sensitivity analysis. The intention to treat approach was adopted, assuming participants lost to follow-up did not change their smoking behaviors (eg, they made no quit attempts nor changed their daily cigarette consumption) [31]. The acceptability and perceptions of the AR PHWs were reported descriptively using the proportion of participants (%) or mean (SD) as appropriate. Post hoc analyses assessed the difference in 3-month self-reported abstinence, smoking reduction, and quit attempts in the intervention group among those who had ever viewed the AR PHWs and those who had not. All analyses were conducted in Stata/MP (version 15.1; StataCorp). A 2-sided P value $< .05$ was considered statistically significant.

Results

Eighty participants were randomized to the intervention ($n=40$) and control ($n=40$) groups (Figure 2). Table 1 shows that 83% (66/80) of participants were male, 33% (26/80) were aged 50 years or above, and 65% (52/80) had secondary education or less. At baseline, 65% (52/80) had a low level of nicotine dependence, and 81% (65/80) planned to quit beyond 30 days (or were undecided). Baseline characteristics were similar between the 2 groups, except that more participants in the intervention group had tertiary education ($P=.005$). The follow-up retention rates were 74% ($n=59$) at 1 month and 68% ($n=54$) at 3 months; this was similar between the groups ($P=.15$ and $.90$).

Table 2 shows that the intervention group had a slightly higher but not statistically significant self-reported 7-day PPA (7/40, 18% vs 5/40, 13%; RR 1.40, 95% CI 0.48-4.07) and quit attempts (15/40, 38% vs 11/40, 28%; RR 1.36, 95% CI 0.71-2.60) than the control group at 3 months. Similar outcomes were observed after adjusting for levels of education.

Participants in the control group had a higher smoking reduction rate compared to participants in the intervention group after excluding quitters, but the difference was not statistically significant at 3 months (4/33, 12% vs 8/35, 22%; RR 0.50, 95% CI 0.16-1.54).

Table 3 shows that 17 of 40 (43%) participants in the intervention group viewed the AR PHWs. Participants who viewed the AR PHWs rated them as having a mild effect on knowing the adverse consequences of smoking on personal health (mean rating 3.94, SD 3.52), reducing the frequency of buying cigarettes (mean rating 3.29, SD 3.08), perceiving an increase in the importance of quitting (mean rating 3.88, SD

3.50), finding PHWs more disgusting (mean rating 3.41, SD 3.08), and finding PHWs more horrible (mean rating 3.38, SD 3.05).

Table 4 shows the results from a post hoc analysis on viewing AR pictures and SC outcomes in the intervention group. The 3-month self-reported 7-day PPA was higher in those who ever (vs never) viewed AR PHWs (5/17, 29% vs 2/23, 9%). Similar results were observed for quit attempts at 3 months (8/17, 47% vs 7/23, 30%). The participants' characteristics were similar regardless of ever viewing the AR PHWs (Multimedia Appendix 2).

Figure 2. Trial flow chart.

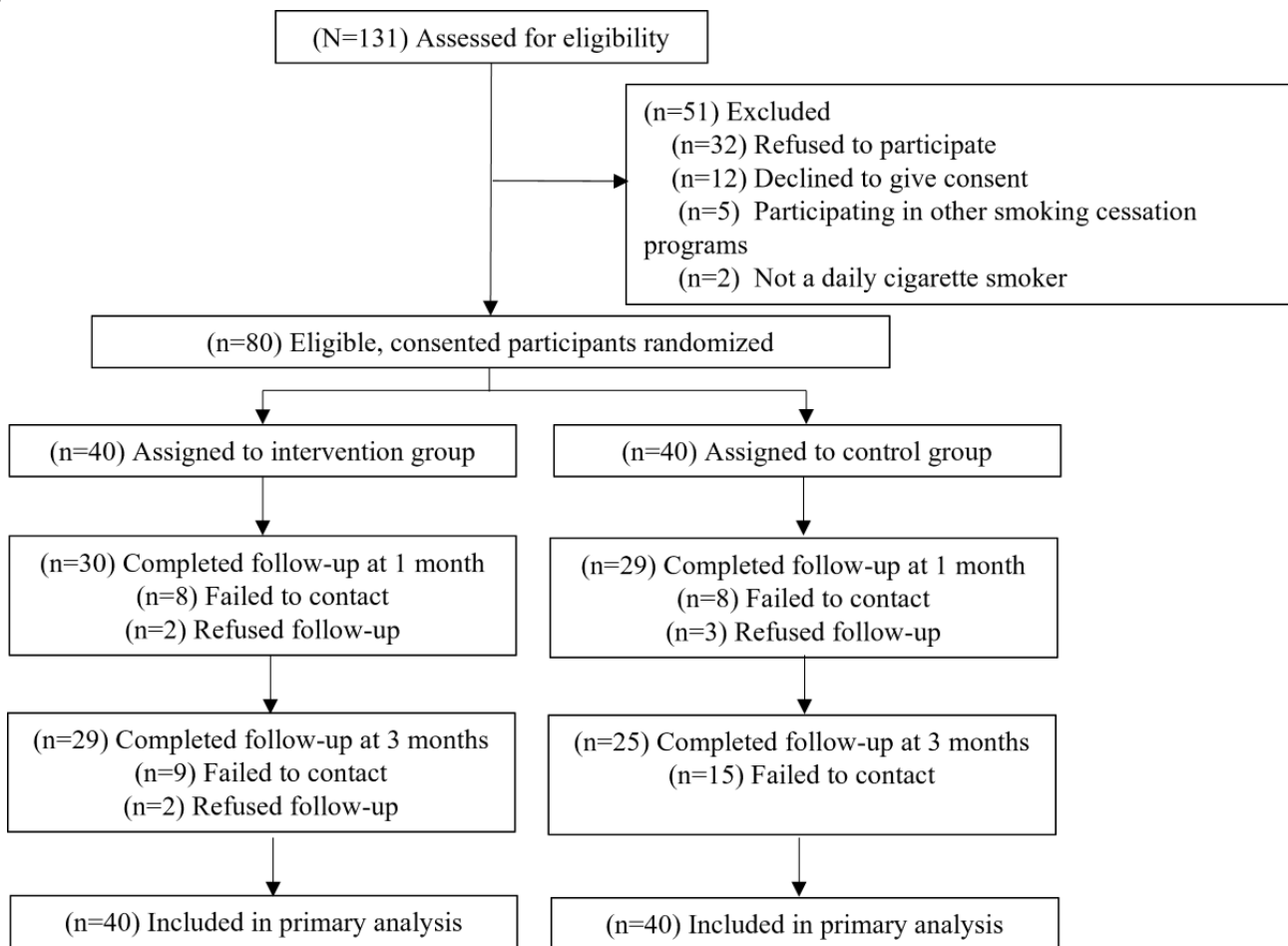


Table 1. Participants' characteristics at baseline (n=80).

Characteristics	Intervention group (n=40)	Control group (n=40)	P value ^a
Sex, n (%)			.24
Male	31 (78)	35 (88)	
Female	9 (23)	5 (13)	
Age (years), n (%)			.78
18-29	8 (20)	5 (13)	
30-39	9 (23)	9 (23)	
40-49	10 (25)	13 (33)	
≥50	13 (33)	13 (33)	
Education, n (%)			.005
Secondary or below	20 (50)	32 (80)	
Tertiary	20 (50)	8 (20)	
Monthly household income (US \$1=HK \$7.80), n (%)			.26
≤\$19,999	7 (26)	13 (41)	
\$20,000-\$29,999	5 (19)	8 (25)	
>\$30,000	15 (56)	11 (34)	
Employment^b, n (%)			>.99
Economically inactive	4 (10)	3 (8)	
Economically active	36 (90)	37 (93)	
Marital status, n (%)			.88
Single	16 (40)	15 (38)	
Married	21 (53)	23 (58)	
Divorced or widowed	3 (8)	2 (5)	
Living with a child younger than 18 years, n (%)			.48
No	28 (70)	25 (63)	
Yes	12 (30)	15 (38)	
Daily cigarette consumption, mean (SD)	12.31 (7.10)	11.31 (6.50)	.51
Nicotine dependency level^c, n (%)			.82
Light	25 (63)	27 (68)	
Moderate	14 (35)	13 (33)	
Heavy	1 (3)	0 (0)	
Past quit attempt, n (%)			.17
Within past 1 month	1 (3)	5 (13)	
Within past 6 months	12 (30)	5 (13)	
Within past 1 year	1 (3)	3 (8)	
More than 1 year	12 (30)	12 (30)	
Never	14 (35)	15 (38)	
Willingness to quit, n (%)			.24
Within 7 days	4 (10)	6 (15)	
Within 30 days	1 (3)	4 (10)	
Within 60 days	2 (5)	1 (3)	
Within 6 months	3 (8)	0 (0)	

Characteristics	Intervention group (n=40)	Control group (n=40)	P value ^a
Undetermined	30 (75)	29 (73)	
Self-efficacy, mean (SD)^d, n (%)			
Perceived confidence of quitting	5.30 (2.57)	5.43 (2.22)	.82
Perceived difficulty of quitting	6.60 (2.31)	6.60 (2.04)	>.99
Perceived importance of quitting	4.83 (2.71)	5.13 (2.27)	.59

^aP values were calculated with the χ^2 test or Fisher exact test for categorical variables and a 2-tailed *t* test for continuous variables.

^bEconomically active: employed or self-employed; economically inactive: student, housekeeper, retired, or unemployed.

^cMeasured by the Heaviness of Smoking Index (HSI): HSI score ≤ 2 =light; HSI score 3-4=moderate; HSI score 5-6=heavy.

^dScore range 0-10; higher scores indicate higher perceived importance, confidence, and difficulty of quitting.

Table 2. Smoking cessation outcomes in intervention vs control groups (N=80)^a.

	Intervention (n=40), n (%)	Control (n=40), n (%)	Cohen ω	Risk ratio (95% CI)	P value	Adjusted risk ratio ^b (95% CI)	P value
Self-reported PPA^c							
1 month	1 (3)	3 (8)	0.11	0.33 (0.04-3.11)	.34	0.35 (0.06-2.03)	.24
3 month	7 (18)	5 (13)	0.07	1.40 (0.48-4.07)	.54	1.17 (0.40-3.39)	.78
Smoking reduction^d							
1 month	3 (8)	5 (14)	0.08	0.60 (0.15-2.36)	.47	0.80 (0.22-2.95)	.74
3 month	4 (12)	8 (22)	0.14	0.50 (0.16-1.54)	.23	0.47 (0.14-1.58)	.22
Quitting attempts							
1 month	10 (25)	11 (28)	0.06	0.91 (0.43-1.91)	.80	0.92 (0.42-2.00)	.84
3 month	15 (38)	11 (28)	0.91	1.36 (0.71-2.60)	.35	1.30 (0.65-2.48)	.49

^aMissing observations were treated as not quitting or reducing.

^aAdjusted for education.

^cPPA: point-prevalence abstinence.

^dAt least a 50% reduction in baseline daily cigarette consumption; participants who self-reported quitting were excluded.

Table 3. Viewing augmented reality (AR) pictures during the intervention period and perceptions of AR pictures (n=40)^a.

	Values
Viewing AR pictures, n (%)	
Never viewed ^a	23 (58)
Viewed	17 (43)
“AR pictures can help to...” (ratings of perceptions), mean (SD)	
Know the adverse consequences of smoking on personal health	3.94 (3.52)
Increase the perceived importance of quitting	3.88 (3.50)
Reduce the frequency of buying cigarettes	3.29 (3.08)
Perceive pictorial health warnings as more disgusting	3.41 (3.08)
Perceive pictorial health warnings as more horrible	3.38 (3.05)

^aMissing observations were treated as never having viewed the AR pictures.

Table 4. Smoking cessation outcomes at 3 months by whether participants had viewed the augmented reality (AR) pictures during the intervention period in the intervention group (n=40)^a.

	Never viewed AR pictures (n=23), n (%)	Viewed AR pictures (n=17), n (%)	P value
Self-reported PPA ^b	2 (9)	5 (29)	.11
Smoking reduction ^c	3 (13)	1 (6)	.43
Quit attempts	7 (30)	8 (47)	.28

^aMissing observations were treated as never having viewed the AR pictures.

^bPPA: point-prevalence abstinence.

^cAt least a 50% reduction in baseline daily cigarette consumption; participants who self-reported quitting were excluded.

Discussion

Principal Findings

This is the first pilot RCT of mobile-based AR PHWs for SC in community smokers, showing that this approach was feasible and increased self-reported abstinence and quit attempts when provided on top of chat-based SC support. The 3-month 7-day PPA in the intervention (18%) and control (13%) groups in this study was comparable to that (15%) in our previous chat-based intervention for SC in 1185 smokers [2]. Notably, a direct comparison is not appropriate because of differences in the participants' characteristics and the intervention. Our study adds to the literature on the potential of AR for SC.

Despite most of the participants having low willingness to quit at baseline, nearly half (17/40, 43%) of the intervention group participants viewed the AR PHWs. This might be due to the attractiveness of the novel AR modality and demonstrates the feasibility and acceptability of delivering AR intervention through mobile phones to community smokers. AR can vividly show the progression of diseases caused by smoking in an immersive, interactive manner, which might improve viewers' acceptance of the warning information. Future mobile health (mHealth) SC interventions can involve AR as one component to attract and engage participants; mHealth interventions have been reported to have suboptimal engagement [32,33]. Notably, our AR links required scanning 6 types of PHWs on cigarette packs to activate the augmentation. Cigarettes with 12 types of PHWs are displayed in retail stores randomly, and participants bought cigarettes according to their preferences. Each type of package thus had a set PHW, and PHWs from other cigarette packages were lacking, which might have led to some AR PHWs not being activated or viewed. Even though we supplemented the PHWs in the chat-based SC support to mitigate this, supplementation required another device to display these PHWs to enable the activation of the AR content. These factors might have lowered the use of AR in this study. Future web AR content can be further designed with a function to scan pictures stored in the gallery on the users' phones to reduce the burden of requiring another device or picture.

Participants rated the effect of AR PHWs on reducing how many times they bought cigarettes and the effect of evoking disgust and horrible feelings as mild. Our prior territory-wide survey after the implementation of new and enlarged PHWs found that most current smokers in Hong Kong were not considering quitting (69%) or deferring smoking (89.2%) after noticing

PHWs [21]. Local PHWs have not been changed since 2018, and the warning effect of PHWs may be further diminished as a result of repeated viewing [34]. This might have weakened the perceived effect of our local PHW-based AR content on SC and eliciting negative emotions. Further AR content design can be refined by visualizing other adverse consequences of smoking. Apart from showing the deterioration of the organs, which might be familiar to smokers, using AR to show the mechanisms of smoking-related diseases at the microscopic level can be evaluated further. Prior studies have suggested AR can increase antismoking message acceptance by enhancing spatial presence (eg, the feeling of being there) and negative emotions [9,35]. Audio effects (eg, sound and music) to enhance immersion should be included to enhance the effect of AR.

Despite a perceived mild effect, we still observed more smoking abstinence (29% vs 9%) and quit attempts (47% vs 30%) in participants who viewed the AR PHWs compared to those who never did so. Most smokers understand the hazards of smoking but feel self-exemption from the adverse consequences of smoking [8,36]. Our AR was tailored to smoking behaviors, and the participants perceived relatively greater effects on understanding the adverse consequences of smoking on personal health and increasing the perceived importance of quitting. The AR PHWs might help participants connect adverse consequences of smoking with their own smoking behaviors to facilitate quitting.

Our finding of higher, but not statistically significant, smoking abstinence and quit attempts associated with the AR links combined with chat-based SC support could be due to a small sample size, which reduces the power to detect a statistically significant difference [37]. Since community smokers who are unmotivated to quit are less likely to download an SC app [38], we delivered AR links using instant messaging apps. The control group was offered chat-based SC support with similar content and intensity and a similar platform as the attention control. Since chat-based SC support is not usual care and may increase abstinence [2], adopting a strong effectiveness comparison may lead to underestimating the effect of AR PHWs on SC in the real world.

Limitations

This study has some limitations. First, some baseline characteristics were imbalanced, which is common in small-sample trials [22]. Similar results were also observed after adjusting for the imbalances. Second, although a previous study has shown that a proactive recruitment approach can recruit

smokers with demographic and smoking characteristics that are similar to those of general smokers in Hong Kong [39], the participants in this study were younger and more likely to have ever attempted to quit than general smokers (Multimedia Appendix 3). This difference, which might be due to the small sample size in this study, lowers the generalizability of the study findings. Additionally, most participants were male, which was in line with the sex distribution of smokers in Hong Kong [14]. Whether our findings can be generalized to other populations with more female smokers is uncertain. Third, abstinence may have been overreported without biochemical validation. But self-reports of abstinence were more feasible to obtain during the COVID-19 pandemic, and overreporting should have been similar in both groups. Fourth, this pilot study was underpowered to detect the effectiveness of mHealth-based AR PHWs on SC, and although our analysis of the intervention effect on smoking abstinence can be used to generate estimators for a full trial, our results cannot be interpreted as evidence for clinical practice. Fifth, data on the average number of AR PHWs each participant ever viewed were lacking, which might impede the exploration of the association between the dose of AR PHWs and SC. Sixth, the development of the AR PHWs did not involve smokers, which might affect the perception of the AR content

in the intervention and its utility. Posttrial qualitative interviews are warranted to refine the AR content design.

Implications

Considering that previous AR interventions for SC have always adopted a face-to-face approach [13], our findings provide initial evidence to support the feasibility of delivering AR interventions with a mobile modality. If the fully powered trial confirms the effect of the refined AR PHWs on smoking abstinence, mobile-based AR PHWs could be implemented to intervene in smoking behaviors. With the high accessibility of mobile phones, mobile-based AR interventions have the potential to be scalable in the real world, even in remote and resource-poor settings. These findings could also inform the development of mobile-based AR interventions for other harmful behaviors.

Conclusion

We showed the initial feasibility of mobile-based interactive AR content and preliminary evidence on its effectiveness on smoking abstinence. Further AR interventions can consider enhancing participants' immersive experiences and showing other adverse smoking-related consequences to maximize the effect on SC.

Acknowledgments

We thank the participants for their responses to the study and Softmind Ltd for building the augmented reality content. This work was supported by the Seed Fund for Basic Research of the University of Hong Kong.

Data Availability

The data sets in this study are available from the corresponding author on reasonable request.

Authors' Contributions

ZG contributed to project administration, software, formal analysis, methodology, visualization, and writing (original draft, review, and editing). YW contributed to conceptualization, resources, data curation, funding acquisition, validation, visualization, and writing (review and editing). MPW contributed to conceptualization, funding acquisition, supervision, and writing (review and editing). All authors approved the final version of manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Six pictorial health warnings on cigarette packs in Hong Kong.

[DOCX File, 2781 KB - [xr_v1i1e52893_app1.docx](#)]

Multimedia Appendix 2

Characteristics of intervention group participants divided by whether they viewed the augmented reality pictorial health warnings (n=40).

[DOCX File, 17 KB - [xr_v1i1e52893_app2.docx](#)]

Multimedia Appendix 3

Comparisons of the characteristics of the participants in this study and general smokers in Hong Kong.

[DOCX File, 16 KB - [xr_v1i1e52893_app3.docx](#)]

Multimedia Appendix 4

CONSORT-eHEALTH checklist (V 1.6.1).

[PDF File (Adobe PDF File), 92 KB - [xr_v1i1e52893_app4.pdf](#)]

References

1. Wang MP, Suen YN, Li WH, Lam CO, Wu SY, Kwong AC, et al. Intervention with brief cessation advice plus active referral for proactively recruited community smokers: a pragmatic cluster randomized clinical trial. *JAMA Intern Med* 2017 Dec 01;177(12):1790-1797 [FREE Full text] [doi: [10.1001/jamainternmed.2017.5793](#)] [Medline: [29059277](#)]
2. Wang MP, Luk TT, Wu Y, Li WH, Cheung DY, Kwong AC, et al. Chat-based instant messaging support integrated with brief interventions for smoking cessation: a community-based, pragmatic, cluster-randomised controlled trial. *Lancet Digit Health* 2019 Aug;1(4):e183-e192 [FREE Full text] [doi: [10.1016/S2589-7500\(19\)30082-2](#)] [Medline: [33323188](#)]
3. Weng X, Wu Y, Luk TT, Li WHC, Cheung DYT, Tong HSC, et al. Active referral plus a small financial incentive upon cessation services use on smoking abstinence: a community-based, cluster-randomised controlled trial. *Lancet Reg Health West Pac* 2021 Aug;13:100189 [FREE Full text] [doi: [10.1016/j.lanwpc.2021.100189](#)] [Medline: [34527982](#)]
4. Fiore MC, Jaén CR, Baker TB, Tobacco Use and Dependence Guideline Panel. Treating Tobacco Use and Dependence: 2008 Update. Clinical Practice Guideline. US Department of Health and Human Services Public Health Service. 2008 May. URL: <https://www.ncbi.nlm.nih.gov/books/NBK63952/> [accessed 2024-07-19]
5. Noar SM, Hall MG, Francis DB, Ribisl KM, Pepper JK, Brewer NT. Pictorial cigarette pack warnings: a meta-analysis of experimental studies. *Tob Control* 2016 May;25(3):341-354 [FREE Full text] [doi: [10.1136/tobaccocontrol-2014-051978](#)] [Medline: [25948713](#)]
6. Brewer NT, Hall MG, Noar SM, Parada H, Stein-Seroussi A, Bach LE, et al. Effect of pictorial cigarette pack warnings on changes in smoking behavior: a randomized clinical trial. *JAMA Intern Med* 2016 Jul 01;176(7):905-912 [FREE Full text] [doi: [10.1001/jamainternmed.2016.2621](#)] [Medline: [27273839](#)]
7. Sandford A. Government action to reduce smoking. *Respirology* 2003 Mar;8(1):7-16. [doi: [10.1046/j.1440-1843.2003.00436.x](#)] [Medline: [12856736](#)]
8. Drovandi A, Teague P, Glass B, Malau-Aduli B. Do health warnings on cigarette sticks dissuade smokers and non-smokers? A focus group and interview study of Australian university students. *Psychol Res Behav Manag* 2019;12:361-373 [FREE Full text] [doi: [10.2147/PRBM.S193754](#)] [Medline: [31191057](#)]
9. Jung S, Lee J, Biocca F, Kim J. Augmented reality in the health domain: projecting spatial augmented reality visualizations on a perceiver's body for health communication effects. *Cyberpsychol Behav Soc Netw* 2019 Feb;22(2):142-150. [doi: [10.1089/cyber.2018.0028](#)] [Medline: [30668138](#)]
10. Mohan B, Bijlani K, Jayakrishnan R. Simulating consequences of smoking with augmented reality. In: 2015 International Conference on Advances in Computing, Communications and Informatics (ICACCI). New York, NY: IEEE; 2015:919-924.
11. Borovanska Z, Poyade M, Rea P, Buksh I. Engaging with children using augmented reality on clothing to prevent them from smoking. In: Rea PM, editor. *Biomedical Visualisation*. Cham, Switzerland: Springer; 2020:59-94.
12. Vinci C, Brandon KO, Kleinjan M, Hernandez LM, Sawyer LE, Haneke J, et al. Augmented reality for smoking cessation: development and usability study. *JMIR Mhealth Uhealth* 2020 Dec 31;8(12):e21643 [FREE Full text] [doi: [10.2196/21643](#)] [Medline: [33382377](#)]
13. Brandon K, Vinci C, Kleinjan M, Hernandez L, Sawyer L, Sutton S, et al. Testing augmented reality for eliciting cue-provoked urges to smoke: toward moving cue-exposure into the real world. *Nicotine Tob Res* 2021 May 04;23(5):861-865 [FREE Full text] [doi: [10.1093/ntr/ntaa259](#)] [Medline: [33277653](#)]
14. Census and Statistics Department (Hong Kong). URL: https://www.censtatd.gov.hk/en/data/stat_report/product/B1130201/att/B11302752022XXXXB0100.pdf [accessed 2024-12-07]
15. Zhao SZ, Wu Y, Cheung DYT, Luk TT, Weng X, Tong HSC, et al. Increase of unmotivated and hardened smokers in Hong Kong: a repeated cross-sectional trend analysis. *Tob Control* 2024 Jun 20;33(4):481-488. [doi: [10.1136/tc-2022-057724](#)] [Medline: [36878685](#)]
16. McClure JB, Heffner J, Hohl S, Klasnja P, Catz SL. Design considerations for mHealth programs targeting smokers not yet ready to quit: results of a sequential mixed-methods study. *JMIR Mhealth Uhealth* 2017 Mar 10;5(3):e31 [FREE Full text] [doi: [10.2196/mhealth.6845](#)] [Medline: [28283465](#)]
17. Guo N, Luk TT, Wu YS, Guo Z, Chu JCL, Cheung YTD, et al. Effect of mobile interventions with nicotine replacement therapy sampling on long-term smoking cessation in community smokers: A pragmatic randomized clinical trial. *Tob Induc Dis* 2023;21:44 [FREE Full text] [doi: [10.18332/tid/160168](#)] [Medline: [36969982](#)]
18. Weng X, Luk TT, Wu YS, Zhao SZ, Cheung DYT, Tong HSC, et al. Effect of smoking-related COVID-19 risk messaging on smoking cessation in community smokers: A pragmatic randomized controlled trial. *Tob Induc Dis* 2023 Jun;21:77 [FREE Full text] [doi: [10.18332/tid/163176](#)] [Medline: [37323509](#)]
19. BinDhim NF, McGeechan K, Trevena L. Who uses smoking cessation apps? A feasibility study across three countries via smartphones. *JMIR Mhealth Uhealth* 2014 Feb 06;2(1):e4 [FREE Full text] [doi: [10.2196/mhealth.2841](#)] [Medline: [25098439](#)]
20. Countries and jurisdictions with pictorial health warning labels, by size. Campaign for Tobacco-Free Kids. URL: https://www.tobaccofreekids.org/assets/global/pdfs/en/WL_country_size.pdf [accessed 2024-07-12]

21. Wu Y, Wang M, Cheung D, Lee P, Ho D, Kwong A, et al. Effectiveness of new and enlarged pictorial health warnings on cigarette packs tobacco control policy-related surveys 2018. COSH Report No 27 2020. Legislative Council Commission (Hong Kong). URL: <https://www.legco.gov.hk/yr20-21/english/panels/hs/papers/hscb2-516-1-e.pdf> [accessed 2024-07-12]
22. Eldridge SM, Chan CL, Campbell MJ, Bond CM, Hopewell S, Thabane L, PAFS consensus group. CONSORT 2010 statement: extension to randomised pilot and feasibility trials. *BMJ* 2016 Oct 24;355:i5239 [FREE Full text] [doi: [10.1136/bmj.i5239](https://doi.org/10.1136/bmj.i5239)] [Medline: [27777223](https://pubmed.ncbi.nlm.nih.gov/27777223/)]
23. Wu YS, Cheung YTD, Lee JJJ, Wong CKH, Ho SY, Li WHC, et al. Effect of adding personalized instant messaging apps to a brief smoking cessation model in community smokers in Hong Kong: pragmatic randomized clinical trial. *J Med Internet Res* 2024 May 13;26:e44973 [FREE Full text] [doi: [10.2196/44973](https://doi.org/10.2196/44973)] [Medline: [38739429](https://pubmed.ncbi.nlm.nih.gov/38739429/)]
24. Weng X, Lau OS, Ng CH, Li WHC, Lam TH, Wang MP. Effect of a workplace mobile phone-based instant messaging intervention on smoking cessation: a cluster-randomized controlled trial. *Addiction* 2022 Jun;117(6):1758-1767. [doi: [10.1111/add.15804](https://doi.org/10.1111/add.15804)] [Medline: [35037319](https://pubmed.ncbi.nlm.nih.gov/35037319/)]
25. Miller W, Rollnick S. *Motivational Interviewing: Preparing People for Change*, 2nd Ed. New York, NY: The Guilford Press; 2002.
26. Prochaska JO, DiClemente CC. Stages and processes of self-change of smoking: toward an integrative model of change. *J Consult Clin Psychol* 1983 Jun;51(3):390-395. [doi: [10.1037//0022-006x.51.3.390](https://doi.org/10.1037//0022-006x.51.3.390)] [Medline: [6863699](https://pubmed.ncbi.nlm.nih.gov/6863699/)]
27. Heatherton T, Kozlowski L, Frecker R, Rickert W, Robinson J. Measuring the heaviness of smoking: using self-reported time to the first cigarette of the day and number of cigarettes smoked per day. *Br J Addict* 1989 Jul;84(7):791-799 [FREE Full text] [doi: [10.1111/j.1360-0443.1989.tb03059.x](https://doi.org/10.1111/j.1360-0443.1989.tb03059.x)] [Medline: [2758152](https://pubmed.ncbi.nlm.nih.gov/2758152/)]
28. Zhao SZ, Wu YS, Chau SL, Fong DYT, Lam TH, Wang MP. Mobile chat-based support plus nicotine replacement therapy sampling to promote smoking cessation for community smokers: A randomized controlled trial. *Tob Induc Dis* 2021;19:32 [FREE Full text] [doi: [10.18332/tid/133373](https://doi.org/10.18332/tid/133373)] [Medline: [33927586](https://pubmed.ncbi.nlm.nih.gov/33927586/)]
29. Keijsers M, Vega-Corredor MC, Tomintz M, Hoermann S. Virtual reality technology use in cigarette craving and smoking interventions (I "virtually" quit): systematic review. *J Med Internet Res* 2021 Sep 17;23(9):e24307 [FREE Full text] [doi: [10.2196/24307](https://doi.org/10.2196/24307)] [Medline: [34533471](https://pubmed.ncbi.nlm.nih.gov/34533471/)]
30. Zou G. A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol* 2004 Apr 01;159(7):702-706. [doi: [10.1093/aje/kwh090](https://doi.org/10.1093/aje/kwh090)] [Medline: [15033648](https://pubmed.ncbi.nlm.nih.gov/15033648/)]
31. West R, Hajek P, Stead L, Stapleton J. Outcome criteria in smoking cessation trials: proposal for a common standard. *Addiction* 2005 Mar;100(3):299-303. [doi: [10.1111/j.1360-0443.2004.00995.x](https://doi.org/10.1111/j.1360-0443.2004.00995.x)] [Medline: [15733243](https://pubmed.ncbi.nlm.nih.gov/15733243/)]
32. Eysenbach G. The law of attrition. *J Med Internet Res* 2005 Mar 31;7(1):e11 [FREE Full text] [doi: [10.2196/jmir.7.1.e11](https://doi.org/10.2196/jmir.7.1.e11)] [Medline: [15829473](https://pubmed.ncbi.nlm.nih.gov/15829473/)]
33. Kohl LFM, Crutzen R, de Vries NK. Online prevention aimed at lifestyle behaviors: a systematic review of reviews. *J Med Internet Res* 2013 Jul 16;15(7):e146 [FREE Full text] [doi: [10.2196/jmir.2665](https://doi.org/10.2196/jmir.2665)] [Medline: [23859884](https://pubmed.ncbi.nlm.nih.gov/23859884/)]
34. Hammond D, Fong GT, Borland R, Cummings KM, McNeill A, Driezen P. Text and graphic warnings on cigarette packages: findings from the international tobacco control four country study. *Am J Prev Med* 2007 Mar;32(3):202-209 [FREE Full text] [doi: [10.1016/j.amepre.2006.11.011](https://doi.org/10.1016/j.amepre.2006.11.011)] [Medline: [17296472](https://pubmed.ncbi.nlm.nih.gov/17296472/)]
35. Lee J, Jung S, Kim JW, Biocca F. Applying spatial augmented reality to anti-smoking message: focusing on spatial presence, negative emotions, and threat appraisal. *Int J Hum Comput Interact* 2018 Jul 09;35(9):751-760. [doi: [10.1080/10447318.2018.1489581](https://doi.org/10.1080/10447318.2018.1489581)]
36. O'Hegarty M, Pederson LL, Nelson DE, Mowery P, Gable JM, Wortley P. Reactions of young adult smokers to warning labels on cigarette packages. *Am J Prev Med* 2006 Jun;30(6):467-473. [doi: [10.1016/j.amepre.2006.01.018](https://doi.org/10.1016/j.amepre.2006.01.018)] [Medline: [16704939](https://pubmed.ncbi.nlm.nih.gov/16704939/)]
37. Thabane L, Ma J, Chu R, Cheng J, Ismaila A, Rios LP, et al. A tutorial on pilot studies: the what, why and how. *BMC Med Res Methodol* 2010 Jan 06;10:1 [FREE Full text] [doi: [10.1186/1471-2288-10-1](https://doi.org/10.1186/1471-2288-10-1)] [Medline: [20053272](https://pubmed.ncbi.nlm.nih.gov/20053272/)]
38. Borrelli B, Bartlett YK, Tooley E, Armitage CJ, Wearden A. Prevalence and frequency of mHealth and eHealth Use among US and UK smokers and differences by motivation to quit. *J Med Internet Res* 2015 Jul 04;17(7):e164 [FREE Full text] [doi: [10.2196/jmir.4420](https://doi.org/10.2196/jmir.4420)] [Medline: [26149323](https://pubmed.ncbi.nlm.nih.gov/26149323/)]
39. Wang MP, Li WHC, Jiang N, Chu LY, Kwong A, Lai V, et al. e-Cigarette awareness, perceptions and use among community-recruited smokers in Hong Kong. *PLoS One* 2015;10(10):e0141683 [FREE Full text] [doi: [10.1371/journal.pone.0141683](https://doi.org/10.1371/journal.pone.0141683)] [Medline: [26502284](https://pubmed.ncbi.nlm.nih.gov/26502284/)]

Abbreviations

AR: augmented reality

AWARD: ask, warn, advise, referral, do-it-again

CONSORT: Consolidated Standards of Reporting Trials

HSI: Heaviness of Smoking Index

IM: instant messaging

mHealth: mobile health

MI: motivational interviewing
PHW: pictorial health warning
PPA: point-prevalence abstinence
RCT: randomized controlled trial
RR: risk ratio
SC: smoking cessation

Edited by T Leung; submitted 19.09.23; peer-reviewed by V Hui, S Comulada; comments to author 13.02.24; revised version received 02.05.24; accepted 08.07.24; published 01.08.24.

Please cite as:

Guo Z, Wu Y, Wang MP

Mobile Phone-Based Personalized and Interactive Augmented Reality Pictorial Health Warnings for Enhancing a Brief Advice Model for Smoking Cessation: Pilot Randomized Controlled Trial

JMIR XR Spatial Comput 2024;1:e52893

URL: <https://xr.jmir.org/2024/1/e52893>

doi: [10.2196/52893](https://doi.org/10.2196/52893)

PMID:

©Ziqiu Guo, Yongda Wu, Man Ping Wang. Originally published in JMIR XR and Spatial Computing (<https://xr.jmir.org>), 01.08.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR XR and Spatial Computing, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Original Paper

Assessing Predictive Factors of Attitudes Toward Peer-Supported Mental Health Interventions in the Metaverse: Mixed Methods Study

Francisco Nicolas Ramos¹, BA; Rachel A Bernstein¹, BA; Iony D Ezawa¹, PhD

Department of Psychology, University of Southern California, Los Angeles, CA, United States

Corresponding Author:

Iony D Ezawa, PhD

Department of Psychology

University of Southern California

3620 S McClintock Ave

Los Angeles, CA, 90089

United States

Phone: 1 (213) 740 2203

Email: ezawa@usc.edu

Abstract

Background: The metaverse is a promising avenue for accessible, effective digital mental health treatments. However, general attitudes toward peer-supported metaverse mental health interventions (MMHIs) remain largely unexplored.

Objective: This study examined the relation of sociodemographic, mental health, and technology factors in predicting attitudes toward MMHIs.

Methods: We used a mixed methods design with a self-report online survey (N=545 participants) to assess participant attitudes toward MMHIs and sociodemographic, mental health, and technology factors. Ordinal logistic regression was used to examine predictors of general interest in peer-supported MMHIs and binary logistic regression to examine predictors of preference for MMHIs versus face-to-face interventions. Inductive content analysis was performed on 483 open-ended responses regarding intervention preference.

Results: Older age (odds ratio [OR] 1.03, 95% CI 1.02-1.05; $P<.001$), higher ethnic identity centrality (OR 1.44, 95% CI 1.25-1.66; $P<.001$), more positive mental help-seeking attitudes (OR 1.22, 95% CI 1.06-1.42; $P=.007$), more online video game use (OR 1.26, 95% CI 1.09-1.44; $P=.001$), and greater virtual reality experience (OR 1.55, 95% CI 1.28-1.90; $P<.001$) were associated with greater odds of reporting more interest in MMHIs. Internet access was associated with greater odds of reporting less interest in MMHIs (OR 0.50, 95% CI 0.30-0.84; $P=.01$). Hispanic ethnicity (OR 1.81, 95% CI 1.13-2.90; $P=.01$), older age (OR 1.04, 95% CI 1.02-1.05; $P<.001$), higher ethnic identity centrality (OR 1.28, 95% CI 1.09-1.51; $P=.003$), smartphone access (OR 10.46, 95% CI 2.87-50.71; $P<.001$), higher self-reported video game use (OR 1.25, 95% CI 1.05-1.48; $P=.01$), and more positive computer attitudes (OR 1.05, 95% CI 1.01-1.10; $P=.02$) predicted greater odds of preference for MMHIs (versus face-to-face interventions), whereas the male gender (OR 0.43, 95% CI 0.28-0.68; $P<.001$), internet access (OR 0.12, 95% CI 0.02-0.40; $P=.002$), more positive mental help-seeking attitudes (OR 0.76, 95% CI 0.62-0.92; $P=.005$), and moderately severe (OR 0.20, 95% CI 0.07-0.51; $P=.001$) and severe (OR 0.26, 95% CI 0.08-0.79; $P=.02$) levels of depression symptoms predicted lower odds of preference for MMHIs. Qualitative analysis revealed 14 themes describing reasons for intervention preference. Anonymity (133/483, 27.5%), social aversion (38/483, 7.9%), ease of use and accessibility (35/483, 7.2%), anxiety (28/483, 5.8%), and comfort (26/483, 5.4%) tended to be endorsed by those preferring MMHIs. Ecological validity of social interactions (99/483, 20.5%), ecological validity of interventions (75/483, 15.5%), aversion/distrust toward technology (42/483, 8.7%), impersonal quality (31/483, 6.4%), and immersion/engagement (11/483, 2.3%) tended to be endorsed by those who preferred face-to-face interventions. Mental health attitudes (28/483, 5.8%), privacy (19/483, 3.9%), and miscellaneous reasons (46/483, 9.5%) were endorsed equally between preferences. Novelty (21/483, 4.3%) was most cited by those who expressed no preference.

Conclusions: This study identified several factors associated with attitudes toward peer-supported MMHIs, which may be leveraged to inform mental health outreach to interested populations.

(JMIR XR Spatial Comput 2024;1:e57990) doi:[10.2196/57990](https://doi.org/10.2196/57990)

KEYWORDS

metaverse; mental health intervention; consumer attitude; digital mental health intervention; virtual world

Introduction

Background

In efforts to connect mental health services with those in need, novel technologies are increasingly used to facilitate mental health treatment. Recently, there has been significant development in the technology of the metaverse and its implications for the future of health care [1,2]. The metaverse, a collection of enduring, interoperable 3D virtual worlds in which people interact with each other and the environment using virtual avatars [3], shows promise as a platform for mental health interventions for several reasons. First, metaverse mental health interventions (MMHIs) are situated *between* technology-based interventions (which use technology to create unique therapeutic affordances) and mere technology-facilitated interventions (eg, psychotherapy delivered by video calls) [4]. This is because MMHIs use customizable, anonymous avatars to mediate social communication, which may appeal to individuals who would otherwise not seek treatment due to stigma, anxiety, or fear of discrimination in face-to-face therapy [5-8]. Second, MMHIs share many of the advantages of the wider umbrella of digital mental health interventions (DMHIs), including a controlled environment with integrated data collection and accessibility from a range of devices and locations [9]. Third, the social aspect of the metaverse offers simple integration of peer support programs [8]. Research suggests online peer support to be associated with improved depression symptomatology [10,11] and general peer support with increased engagement and efficacy in internet therapies [12].

The investigation of attitudes toward peer-supported MMHIs is critical to their development because it will aid in the identification of populations for whom MMHIs may facilitate mental help-seeking, as well as of barriers to seeking out these types of interventions. We are not aware of any research assessing factors that may influence attitudes toward MMHIs, but the broader literature on DMHIs suggests several factors that may have a significant impact on attitudes toward MMHIs.

Sociodemographic Factors

Research assessing the associations between common sociodemographic factors and attitudes toward DMHIs presents mixed results. For example, previous studies evaluating attitudes toward DMHIs report conflicting results as to whether associations with gender or age exist, as well as the direction of the associations found [13-17]. However, because the umbrella of interventions that can be defined as DMHIs is broad, these studies assess different interventions, from online peer support groups [13] to online psychotherapy delivered by a professional [17]. The investigation of attitudes toward peer-supported MMHIs is narrow in scope, which may aid in accuracy in identifying the relationships between relevant sociodemographic factors and attitudes toward peer-supported MMHIs. In addition, several key sociodemographic factors that could be associated with attitudes toward MMHIs have not been previously evaluated in the DMHI literature. Technological

access variables, such as internet access, are negatively associated with self-reported poor mental health [18] and could have a relationship with how one perceives the accessibility, pricing, or usability of technology-based MMHIs. Lastly, ethnic identity centrality (the importance one's ethnicity has to their identity as a whole) could play a role in attitudes toward MMHIs due to the use of customizable avatars that participants can use to either hide or highlight parts of their identities. It is critical to assess the sociodemographic factors that correlate with attitudes toward MMHIs in order to understand which populations may be particularly willing or unwilling to use MMHIs.

Mental Health Factors

Synchronous DMHIs may be preferred to face-to-face interventions for individuals experiencing common mental health disorders, such as anxiety (particularly social anxiety) and depression, due to reduced social interaction-related stress [19] and reduced stigma and embarrassment when the DMHI is anonymous [20]. MMHIs are synchronous and anonymous, which may make them particularly attractive to individuals with elevated levels of social anxiety or depression symptoms. Furthermore, negative attitudes toward mental help-seeking remain a barrier to the use of DMHIs [20]. The unique features of MMHIs, such as their ability to balance a sense of presence and anonymity [7], may prove attractive to those who would otherwise not seek treatment due to negative attitudes toward mental help-seeking.

Technology Factors

Attitudes toward technology appear to be generally related to attitudes toward DMHIs [21]. Since the metaverse and virtual worlds are historically computer based [22], attitudes toward computers specifically may be related to attitudes toward peer-supported MMHIs. Moreover, peer-supported MMHIs share strong mechanistic similarities with online multiplayer video games. Not only do such games facilitate anonymous communication and group social interaction, but most of the mechanics and navigation elements of MMHIs would be familiar to gamers, such as "avatars," "push to talk" buttons, and immersion in a virtual world. Online video game use may, therefore, be a pertinent factor in attitudes toward peer-supported MMHIs.

Study Aims

The aim of this study was to assess factors that may predict general interest in MMHIs, as well as preference for MMHIs versus face-to-face interventions. To accomplish this objective, we conducted a web-based survey in a diverse sample from the general population to assess sociodemographic, mental health, and technology factors that could be associated with attitudes toward peer-supported MMHIs.

Methods

Study Design

This study involved a mixed methods design with data gathered from an open, voluntary, web-based survey. The online survey included a variety of quantitative self-report measures of attitudes toward different interventions, sociodemographic factors, mental health factors, and technology factors. The survey also included open-ended questions used to gather qualitative data on participants' reasons for their attitudes toward intervention types. We chose this study design because it is feasible for participants and can easily reach a large, diverse sample. Reporting followed the Checklist for Reporting Results of Internet E-Surveys (CHERRIES; see [Multimedia Appendix 1](#) for the checklist) [23].

Recruitment

Inclusion criteria for the study were (1) ability and willingness to provide informed consent and (2) age of 18 years or above. There were no exclusion criteria for this study. Participants meeting these criteria were recruited to participate in the survey using word-of-mouth, flyers distributed around our university campus, social media posts on the networks Reddit and X (formerly Twitter), and Prolific (a web-based recruitment platform) [24]. Recruitment occurred from April to July 2023. Initial contacts for recruitment occurred online via the social media posts, except for a few individuals who received a paper flyer on our university campus. For social media, a single post was made to each social media site with information about the study and a direct link to complete the study consent form and survey. The survey was posted 4 times on Prolific to target different individuals identifying as part of various racial/ethnic groups (using Prolific's available demographic-screening options).

We calculated our anticipated sample size using the recommendation of at least 10 events per variable in a logistic regression [25-27]. This recommendation helps avoid overfitting and biased estimates. We originally planned to include 19 predictors in our model, which resulted in an estimated sample size of 380 participants. However, some of these predictors were removed after preliminary examination of the data (eg, presence of highly related predictors). This recommendation is only a minimum, and a higher number of events per variable is almost always preferable [28]. Due to the unexpected strong success of our recruitment strategies, recruitment continued until we could no longer fund recruitment.

Procedures

Participants who accessed the study link via the online posts or by scanning the QR code on paper flyers were redirected to a University of Southern California (USC) Qualtrics page and presented with an information sheet for the study. The information sheet included the estimated study length of 9 minutes and a data storage policy for the collection of anonymous data. Participants were then asked to provide consent. Those who consented to participate in the study were asked to complete a series of self-report measures assessing sociodemographic, mental health, and technology factors.

Participants were then asked to watch a short video clip showing an example of a mental health intervention taking place in the metaverse (Innerworld, developed by Innerworld, Inc [7], was used as an example of a peer-supported MMHI). Lastly, participants completed measures of their attitudes toward MMHIs. Prolific participants were compensated with US \$2 for completing the survey, while all other participants were provided with the chance to be selected for a US \$100 gift card raffle.

The survey was hosted on Qualtrics with a black-and-white color scheme and official USC branding. We implemented IP address monitoring and browser cookie measures in Qualtrics in order to prevent the same user from completing the survey multiple times during the duration of the study. The survey's usability and functionality were assessed by investigators and close colleagues prior to data collection. An attention check question was included, which participants had to answer correctly to proceed with the survey. The survey used adaptive questioning to reduce participant burden, but we did not randomize the order of items or question blocks for individual participants. Respondents could not review previous answers. Completeness was reported automatically by Qualtrics, but survey responses were also reviewed manually. Fraudulent responses were removed after a thorough examination, including checking for impossible or exceptionally fast time stamps (at least 3 SDs below the mean duration), abnormally low clicks counted, nonsensical or artificial intelligence (AI)-generated open-ended responses, and "straight-lined" answers.

Ethical Considerations

This study was approved by the USC's Institutional Review Board at the exempt level (approval number: UP-23-00491). Data were anonymized and contained no identifying information.

Measures

Sociodemographic Factors

Participants were asked to provide their ethnicity/race, gender identity, and age. Participants were also asked whether they had access to the internet or a smartphone or both. Consistent with prior work on ethnic identity centrality [29-31], we asked participants to indicate their level of ethnic identity centrality ("How important is your racial or ethnic background to your identity as a whole?") on a 5-point scale ranging from 1 (not at all important) to 5 (extremely important).

Mental Health Factors

Mental Help-Seeking Attitudes

The Mental Help Seeking Attitudes Scale (MHSAS), a 9-item self-report measure, was used to evaluate participant attitudes toward seeking help from a mental health professional. The MHSAS is a validated [32] bipolar scale with 7 response options to each item anchored on either end by dichotomous adjectives (eg, good, bad). A mean total score is computed, with higher scores indicating more positive attitudes toward seeking mental help.

Level of Depression Symptoms

Depression symptoms were measured using the 8-item Patient Health Questionnaire (PHQ-8), a well-validated and reliable self-report measure of depression symptoms [33]. Each item is rated on a 0–3-point Likert scale, and a sum total score is computed, with higher scores indicating greater depression symptom severity. This variable was categorized according to severity categories set by the authors of this instrument: 0–4 indicating no symptoms, 5–9 indicating mild symptoms, 10–14 indicating moderate symptoms, 15–19 indicating moderately severe symptoms, and ≥ 20 indicating severe symptoms.

Level of Social Anxiety Symptoms

Social anxiety symptoms were measured using the Mini-Social Phobia Inventory (Mini-SPIN) [34]. The Mini-SPIN is a validated [35–37] 3-item self-report screening tool that asks participants to rate, in the past week, how much (ranging from 0 for *not at all* to 4 for *extremely*) they have been bothered by problems related to social anxiety. A sum total score is computed, with higher scores indicating greater social anxiety symptom severity. This variable was dichotomized based on suggestions from the authors of this instrument, with a score of 6 or greater indicating the presence of a clinical level of symptom severity.

Technology Factors

Computer Attitudes

To evaluate attitudes toward using computers, we adapted the Computer Attitudes subscale of the well-validated Computer Aversion, Attitudes, and Familiarity Index (CAAFI) [38–40]. The subscale consists of 9 items asking participants to select the response, ranging from –3 (absolutely false) to 3 (absolutely true), that best describes how true or false a statement is to them. A sum total score is computed, with higher scores indicating more positive attitudes toward using computers. We removed 3 items that were outdated with regard to the cultural mass usage of computers and email in the recent decade (“I use a computer input device every day,” “I use email every day,” and “Email is an easy way to communicate with people.”).

Video Game/Internet Use Habits

Similarly to previous research assessing internet habits [41,42], participants self-reported how often (ranging from 1 for *never* to 5 for *very often*) they engaged in specific activities while connected to the internet (eg, “playing online video games”).

Virtual Reality Experience

Consistent with prior work [43,44], we used a single item with 4 response options ranging from 1 (no experience) to 4 (a lot of experience) to assess participants’ previous experience with virtual reality (VR) technology.

Outcome Variables

General Interest in Peer-Supported MMHIs

We adapted a single-item measure commonly used across disciplines to assess overall willingness to use a peer-supported MMHI [45,46]. Participants were asked how willing they would be to use a peer-supported MMHI if money was not a concern,

with response options ranging from 1 (not at all willing) to 5 (extremely willing).

Preference for Peer-Supported MMHIs Versus Face-to-Face Interventions

A single item asked whether participants would prefer to use a peer-supported MMHI or a face-to-face peer-supported mental health intervention. A 5-point scale was used such that participants could either indicate no preference, a mild preference (somewhat prefer), or a strong preference (definitely prefer) for either MMHIs or face-to-face interventions.

Qualitative Variables

After participants were asked whether they would prefer to use a peer-supported MMHI or a face-to-face peer-supported mental health intervention, an open-ended question asked their reasoning behind their preference. At the end of the survey, another open-ended question asked whether there was anything else the participants wanted to share with the research team (see [Multimedia Appendix 2](#) for a copy of each investigator-devised scale and items used for this study).

Analytic Strategy

Quantitative data were analyzed using R version 4.3.1 [47]. In instances of missing item-level data, we prorated scores by averaging the available items. Before proration, 62 (11.4%) participant responses had some level of missingness across measures. After proration, 40 (7.3%) participant responses still contained some level of missingness across measures.

Quantitative Analyses

To examine predictors of interest in MMHIs, we conducted ordinal logistic regression, designed for modeling an ordinal dependent variable [48], in a 2-step approach. In the first stage, we ran a comprehensive model of the complete list of 13 predictors: Hispanic ethnicity, the male gender, age, income, ethnic identity centrality, internet access, smartphone access, mental help-seeking attitudes, the level of depression symptoms, the level of social anxiety symptoms, computer attitudes, self-reported video game use, and experience with VR. In the second stage, we evaluated a parsimonious model that retained the predictors that were significant in the comprehensive model at $P < .10$, similar to the procedures used previously to examine predictors of response variables in digital interventions [49,50].

Given the bimodal distribution of preference for MMHIs versus face-to-face interventions responses, we dichotomized this outcome variable. To examine the predictors of MMHI versus face-to-face intervention preference, we conducted binary logistic regression using the same 2-stage approach described earlier.

To ensure the validity of the modeling approaches, we checked the assumptions of each comprehensive and parsimonious model. For ordinal logistic regression, we visually assessed the distribution of responses in our outcome variable (ie, interest in MMHIs) and noticed that responses indicating little to no interest (scores of 1 and 2) were highly associated with each other and responses indicating moderate-to-strong interest (scores of 4 and 5) were highly associated with each other. Although interest in MMHIs was relatively normally distributed,

this raised concern for the validity of the proportional odds assumption in this data, which posits that the relationship (and, therefore, the odds ratio [OR] of coefficients) between each pair of outcome groups is the same [48]. As such, we collapsed the variable for interest in MMHIs into 3 categories: low interest (score of 1 or 2), neutral (score of 3), and high interest (score of 4 or 5). We checked for violations of the proportional odds assumption in the ordinal logistic model using the Brant test. For binary logistic regression, we visually checked for violations of the logit-linearity assumption between the outcome variable (ie, intervention preference) and continuous predictors. We assessed Cook's distance and studentized residual plots for each comprehensive and parsimonious binary logistic regression to detect potential outliers. Five outliers were removed from the comprehensive binary logistic regression model. Lastly, we checked for multicollinearity in both parsimonious models, with a variance inflation factor of 4 or greater indicating high multicollinearity [51].

Results of a Wilcoxon rank sum test showed that Prolific participants reported a significantly lower mean MMHI interest compared to the non-Prolific sample ($W=27258$, $P=.04$). Therefore, we included *recruitment method* as a covariate in our model examining predictors of MMHI interest, which did not alter the direction or significance of results. We did not find

a significant difference in MMHI versus face-to-face intervention preference with respect to recruitment method.

Qualitative Analyses of Open-Ended Responses

We conducted an inductive content analysis [52] on open-ended responses explaining participant preference for MMHIs versus face-to-face interventions. Analysis followed all 8 guidelines set out by Cofie et al [53] for maintaining reflexivity and reliability using a qualitative-based measure of intercoder reliability (see [Multimedia Appendix 3](#) for the checklist). Coding was performed using ATLAS.ti version 23.2.3.27778 for Windows [54]. First, authors FNR and RAB conducted an initial review of the data and generated a code framework. Second, all comments were coded by FNR and RAB, who subsequently discussed code groups and definitions and addressed points of contention. This step was repeated 3 times. The analytic process was recorded in research diaries, and no outstanding disagreements were observed after the discussions.

Results

Sample Characteristics

A total of 545 participants completed this study. The median survey completion duration was 8.9 minutes. A full sociodemographic breakdown of the sample assessed in this study is presented in [Table 1](#).

Table 1. Characteristics of participants (N=545) at baseline.

Baseline characteristics	Values
Sociodemographic factors	
Hispanic ethnicity, n (%)	161 (29.6)
Age (years), mean (SD)	34.69 (12.75)
Ethnic identity centrality, mean (SD)	3.04 (1.28)
Access to the internet, n (%)	473 (86.8)
Access to a smartphone, n (%)	490 (89.9)
Gender, n (%)	
Male (reference)	261 (47.9)
Female	265 (48.6)
Genderqueer	2 (0.4)
Nonbinary/nonconforming	14 (2.6)
Unknown	3 (0.6)
Mental health factors, mean (SD)	
Mental help-seeking attitudes	5.58 (1.19)
Depression symptom severity, n (%)	
None	234 (42.9)
Mild	160 (29.4)
Moderate	92 (16.9)
Moderately severe	33 (6.1)
Severe	22 (4.0)
Clinical level of social anxiety symptoms	184 (33.8)
Technology factors, mean (SD)	
Computer attitudes	13.43 (5.94)
Online video game use	3.14 (1.34)
VR ^a experience	2.11 (0.92)

^aVR: virtual reality.

Primary Analyses

General Interest in MMHIs

Regarding general interest in MMHIs, 192 (36.9%) of 520 participants reported low interest, 144 (27.7%) participants reported neutral interest, and 184 (35.4%) reported high interest.

In the parsimonious model, older age, higher ethnic identity centrality, lack of internet access, more positive mental help-seeking attitudes, more online video game use, and more VR experience were associated with greater interest in MMHIs. Results of this parsimonious ordinal logistic model are presented in [Table 2](#) (see [Multimedia Appendix 4](#) for results of the comprehensive ordinal model).

Table 2. Predictors of general interest in peer-supported MMHIs^a in the parsimonious ordinal logistic regression model and predictors of preference for peer-supported metaverse versus face-to-face interventions in the parsimonious binary logistic regression model.

Predictors	Ordinal model			Binary model		
	OR ^b (95% CI)	SE	P value	OR (95% CI)	SE	P value
Hispanic	— ^c	—	—	1.81 (1.13-2.90)	0.24	.01
Male gender	—	—	—	0.43 (0.27-0.68)	0.23	<.001
Age	1.03 (1.02-1.05)	0.007	<.001	1.04 (1.02-1.05)	0.01	<.001
Ethnic identity centrality	1.44 (1.25-1.66)	0.07	<.001	1.28 (1.09-1.51)	0.08	.003
Internet access	0.50 (0.30-0.84)	0.26	.01	0.12 (0.02-0.40)	0.69	.002
Smartphone access	—	—	—	10.46 (2.87-50.71)	0.71	<.001
Mental help-seeking attitudes	1.22 (1.06-1.42)	0.08	.008	0.76 (0.62-0.92)	0.10	.005
Depression symptoms^d						
Mild	—	—	—	0.85 (0.51- 1.42)	0.26	.54
Moderate	—	—	—	0.60 (0.32- 1.12)	0.32	.11
Moderately severe	—	—	—	0.20 (0.07- 0.51)	0.49	.001
Severe	—	—	—	0.26 (0.08- 0.79)	0.58	.02
Computer attitudes	—	—	—	1.05 (1.01-1.10)	0.02	.02
Video game use	1.26 (1.09-1.44)	0.07	.001	1.25 (1.05-1.48)	0.09	.01
VR ^e experience	1.55 (1.28-1.90)	0.10	<.001	—	—	—

^aMMHI: metaverse mental health intervention.

^bOR: odds ratio.

^cNot applicable.

^d“No depression” was used as the reference group for all depression symptom variables.

^eVR: virtual reality.

Preference for MMHIS Versus Face-to-Face Interventions

A total of 233 (42.8%) participants reported preference for MMHIs over face-to-face interventions, 223 (40.9%) participants reported preference for face-to-face interventions over MMHIs, and 64 (11.7%) participants indicated no preference. In the parsimonious model, Hispanic ethnicity, older age, higher ethnic identity centrality, smartphone access, more positive computer attitudes, and higher self-reported video game use were associated with greater odds of preference for MMHIs (versus face-to-face interventions). The male gender, internet access, more positive mental help-seeking attitudes, and higher levels of depression symptoms were associated with lower odds of preference for MMHIs (versus face-to-face interventions). Results of this parsimonious binary logistic model are presented in [Table 2](#) (see [Multimedia Appendix 4](#) for results of the comprehensive binary logistic model).

Qualitative Analyses of Open-Ended Responses

We analyzed 483 comments elaborating on participant preference for peer-supported MMHIs versus peer-supported face-to-face mental health interventions. Analysis revealed 14 codes describing reasons for participants' indicated preference: anonymity; social aversion; anxiety; comfort; ease of use and accessibility; ecological validity of social interaction; ecological validity of intervention; impersonal quality; aversion/distrust

toward technology, the metaverse, or others in the metaverse; mental health attitudes; novelty/experience; privacy; immersion/engagement; and miscellaneous. An overview of the codes and their definitions by preference, as well as representative quotes for each, is presented in [Multimedia Appendix 5](#).

Reasons related to anonymity or benefits of anonymity, such as reduced bias from others (133/483, 27.5%); an aversion to social, particularly face-to-face, interaction (38/483, 7.9%); greater ease of use and accessibility in the preferred intervention (35/483, 7.2%); anxiety, particularly social anxiety (28/483, 5.8%); and greater general comfort/greater comfort with negative feelings in the preferred intervention (26/483, 5.4%) tended to be endorsed by participants who indicated preference for MMHIs. Reasons related to poor ecological validity of social interaction in the nonpreferred intervention, such as lack of body language (99/483, 20.5%); poor ecological validity of the nonpreferred intervention itself, such as unrealistic graphics (75/483, 15.5%); aversion to the metaverse or distrust of affiliated companies or others in the metaverse social space (42/483, 8.7%); an “impersonal quality” of the nonpreferred intervention, often tied to perceived insincerity and overly distant social relations (31/483, 6.4%); and anticipated difficulty remaining engaged in the nonpreferred intervention (11/483, 2.3%) tended to be endorsed by respondents who preferred face-to-face interventions. Reasons related to mental health

attitudes (28/483, 5.8%), privacy (19/483, 3.9%), and miscellaneous points (46/483, 9.5%) were endorsed approximately equally across preferences. The novelty of MMHIs/a lack of experience with MMHIs or mental health interventions (21/483, 4.3%) was most cited by those who expressed no preference.

Discussion

Principal Findings

Our quantitative analysis revealed that older age, higher ethnic identity centrality, lack of internet access, more positive mental help-seeking attitudes, more online video game use, and more VR experience were associated with greater odds of more interest in MMHIs. Hispanic ethnicity, older age, higher ethnic identity centrality, smartphone access, more positive computer attitudes, and higher self-reported video game use were associated with greater odds of preference for MMHIs (versus face-to-face interventions). The male gender, internet access, more positive mental help-seeking attitudes, and higher levels of depression symptoms were associated with lower odds of preference for MMHIs (versus face-to-face interventions). Our qualitative analysis revealed 14 themes related to participants' reasons for why they prefer MMHIs versus face-to-face interventions. Among respondents who preferred MMHIs, reasons cited touched upon themes related to anonymity, social aversion, ease of use and accessibility, anxiety, and comfort. Among those who preferred face-to-face interventions, reasons touched upon ecological validity of social interaction, ecological validity of intervention, aversion/distrust toward technology, impersonal quality, and immersion/engagement. Mental health attitudes, privacy, and miscellaneous reasons were endorsed equally between preferences, and novelty was most cited by those who expressed no preference.

Comparison to Prior Work

Regarding sociodemographic variables, our findings suggest that older adults may be more likely to report higher interest in MMHIs and find MMHIs more attractive than face-to-face interventions, assuaging potential concerns about the accessibility of MMHIs to these individuals [55]. Furthermore, internet access was found to be associated with a lower likelihood of reporting higher interest in MMHIs and of preferring MMHIs to face-to-face interventions. It may be that individuals without internet access are less familiar with the metaverse or online social environments and may find the idea novel and more appealing. Smartphone access was associated with greater odds of preference for MMHIs over face-to-face interventions. Smartphones are often cheaper and more easily accessed than a stable home internet connection, suggesting that those without smartphone access may be particularly averse to or unfamiliar with MMHIs or their type, such as DMHIs. Greater ethnic identity centrality also appeared to be associated with a greater likelihood of reporting higher interest in MMHIs, as well as a greater likelihood of preference for MMHIs versus face-to-face interventions. Qualitative responses from metaverse preferers often seemed to reflect an expectation of reduced bias and discrimination for their race or appearance in MMHIs as opposed to face-to-face interventions, possibly due to lower

salience of identity in the metaverse. Hispanic ethnicity was associated with greater odds of preferring MMHIs as opposed to face-to-face interventions but not associated with interest in MMHIs. It is possible that Hispanics are more likely to prefer MMHIs to face-to-face interventions but not more likely to be interested in using a mental health intervention than non-Hispanics.

Regarding our examination of mental health factors, the greater likelihood of those with more positive attitudes toward mental help-seeking to be more interested in MMHIs might suggest that those who view mental help-seeking more positively may be more likely to view mental health interventions more positively in general. However, the association between more negative attitudes toward mental help-seeking and greater preference for MMHIs versus face-to-face interventions may indicate potential for peer-supported MMHIs to reach out to individuals who otherwise view mental health interventions unfavorably. This was echoed in the qualitative data by respondents who felt that discussing their mental health issues would be easier or less embarrassing in an MMHI than in a face-to-face intervention. However, we also found that participants with moderately severe or severe depression symptoms had greater odds of preferring face-to-face interventions to MMHIs than those with no depression symptoms. This may suggest that peer-supported MMHIs (which are low intensity) may not currently be a more attractive mental health intervention option than face-to-face intervention options for those struggling with more severe depression. Finally, we did not find a relationship between clinical levels of social anxiety symptoms and attitudes toward MMHIs, but our qualitative analysis did reveal a theme of anxiety, wherein comments tended to suggest that the respondents anticipated feeling less nervous in an MMHI than in a face-to-face intervention, often due to their anonymity. The findings regarding the relationship between anxiety and attitudes toward peer-supported MMHIs necessitate further study to elucidate the relationships between these factors.

Finally, the positive association between all 3 technology factors and at least 1 of the outcome variables, combined with the importance of the perceived "realness" of MMHIs and social interactions within them, as revealed in the qualitative analysis, suggests that the digital platform and technological novelty of MMHIs may factor into participant attitudes toward these interventions. However, only online video game use was significant in both ordinal and binary logistic regression models, possibly due to greater conceptual overlap of the videogame-like nature of current MMHIs. The promotion of MMHIs to technologically inclined individuals should be encouraged to connect help-seeking individuals with mental health services they are likely to be interested in. However, our findings also indicate that low ratings on certain technology factors, such as experience with VR, could serve as a barrier to willingness to use an MMHI. Furthermore, given the inconsistent associations between the technological factors measured and our dependent variables, there are likely other technological factors we did not assess that are associated with attitudes toward MMHIs. Attempting to replicate these findings by investigating lack of experience with technology and other technology factors as

potential barriers to seeking MMHIs should be a direction of future research.

Strengths and Limitations

To the best of our knowledge, this is the first study to identify factors associated with general interest in peer-supported MMHIs, as well as preference for peer-supported MMHIs versus peer-supported face-to-face mental health interventions. Our mixed methods approach was able to capture complementary quantitative and qualitative data that can offer a more comprehensive assessment (than either approach alone) of factors influencing participants' attitudes toward MMHIs. However, we noted some limitations of this study. First, we examined a limited number of factors that could influence attitudes toward peer-supported MMHIs. We tried to mitigate this limitation by conducting a thorough review of the literature to identify candidate predictors across a variety of domains (sociodemographic, mental health, and technology). Nonetheless, future work would benefit from investigating other factors. Second, we examined predictive factors of attitudes toward peer-supported MMHIs in a general sample. Assessing these factors in a clinical sample may return different findings that help explain the similarly low level of interest in MMHIs as with face-to-face interventions for individuals with clinical depression or social anxiety. However, we did collect depression and social anxiety symptom data and observed that our sample had representation in each of the symptom severity categories assessed on the measures. Third, it was not always clear what factors an individual participant considered when reporting attitudes. A participant may or may not have considered the metaverse setting, the peer support element, the mental health emphasis, or a number of other factors. Although we sought to contextualize reported preferences using qualitative data, more work is needed to deepen the field's understanding of the most

salient aspects of peer-supported MMHIs that attract or deter participants.

Future Directions

Future work could benefit from assessing the role of other attitudes (eg, attitudes toward companies hosting MMHIs) or technology factors that may be more directly relevant to MMHI use (eg, confidence/competence with technology, number of hours using related technology). We also encourage future research on the acceptability and feasibility of MMHIs with diverse samples to ensure the validity and generalizability of these findings.

Conclusion

This study assessed attitudes toward peer-supported mental health interventions delivered via the metaverse. By identifying sociodemographic, mental health, and technology factors associated with attitudes toward peer-supported MMHIs, our findings represent the first venture into identifying the individuals and populations who may be especially willing to use peer-supported MMHIs or for whom MMHIs may be more attractive than face-to-face interventions (eg, older adults, those with more negative mental help-seeking attitudes). The results of this study serve to inform the future development and outreach plans of MMHIs by identifying populations that may be particularly likely or unlikely to be interested in MMHIs. If replicated, this information could potentially be used to optimize treatment outreach to interested populations, especially those who may not seek mental help otherwise (eg, by increasing the quantity and promotion of technical support, including help documents, to encourage MMHI use by older adults), or to change aspects of MMHIs to better appeal to disinterested populations. Future work is encouraged to confirm the salience of the factors identified in this study to attitudes toward MMHIs and to assess predictive factors of outcomes when using an MMHI.

Data Availability

The data sets generated and analyzed during this study are available from the corresponding author upon reasonable request.

Authors' Contributions

Conceptualization, methodology, project administration, and writing—original draft were managed by FNR and IDE; data curation, formal analysis, and investigation by FNR; supervision by IDE; and writing—review and editing by FNR, RAB, and IDE.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Checklist for Reporting Results of Internet E-Surveys (CHERRIES).

[\[DOCX File, 20 KB - xr_v1i1e57990_app1.docx\]](#)

Multimedia Appendix 2

Investigator-devised scales and items used for this study.

[\[DOCX File, 17 KB - xr_v1i1e57990_app2.docx\]](#)

Multimedia Appendix 3

Checklist of recommendations for reporting intercoder reliability in qualitative research from Cofie et al [53].

[[DOCX File , 17 KB - xr_v1i1e57990_app3.docx](#)]

Multimedia Appendix 4

Results of comprehensive logistic models.

[[DOCX File , 23 KB - xr_v1i1e57990_app4.docx](#)]

Multimedia Appendix 5

Themes from qualitative analysis of open-ended responses.

[[DOCX File , 18 KB - xr_v1i1e57990_app5.docx](#)]

References

1. Benrimoh D, Chheda FD, Margolese HC. The best predictor of the future—the metaverse, mental health, and lessons learned from current technologies. *JMIR Ment Health* 2022 Oct 28;9(10):e40410 [[FREE Full text](#)] [doi: [10.2196/40410](https://doi.org/10.2196/40410)] [Medline: [36306155](https://pubmed.ncbi.nlm.nih.gov/36306155/)]
2. Usmani SS, Sharath M, Mehendale M. Future of mental health in the metaverse. *Gen Psychiatr* 2022 Jul 22;35(4):e100825 [[FREE Full text](#)] [doi: [10.1136/gpsych-2022-100825](https://doi.org/10.1136/gpsych-2022-100825)] [Medline: [36189180](https://pubmed.ncbi.nlm.nih.gov/36189180/)]
3. Ball M. *The Metaverse: And How It Will Revolutionize Everything*. New York, NY: Liveright Publishing Corporation; 2022.
4. Cohen ZD, Schueller SM. Expanding, improving, and understanding behaviour research and therapy through digital mental health. *Behav Res Ther* 2023 Aug;167:104358. [doi: [10.1016/j.brat.2023.104358](https://doi.org/10.1016/j.brat.2023.104358)] [Medline: [37418857](https://pubmed.ncbi.nlm.nih.gov/37418857/)]
5. Andersson G, Titov N. Advantages and limitations of internet-based interventions for common mental disorders. *World Psychiatry* 2014 Feb;13(1):4-11 [[FREE Full text](#)] [doi: [10.1002/wps.20083](https://doi.org/10.1002/wps.20083)] [Medline: [24497236](https://pubmed.ncbi.nlm.nih.gov/24497236/)]
6. Quackenbush D, Krasner A. Avatar therapy: where technology, symbols, culture, and connection collide. *J Psychiatr Pract* 2012 Nov;18(6):451-459. [doi: [10.1097/01.pra.0000422745.17990.be](https://doi.org/10.1097/01.pra.0000422745.17990.be)] [Medline: [23160252](https://pubmed.ncbi.nlm.nih.gov/23160252/)]
7. Robinson N, Mahapatra A, Jean-Baptiste B, Mallard A, Yang A, Hollon SD, et al. Cognitive behavioral immersion for substance use disorders: a feasibility and pilot study of a peer-based coaching program in the metaverse. *Games Health J* 2023 Oct 01;12(5):397-404 [[FREE Full text](#)] [doi: [10.1089/g4h.2022.0214](https://doi.org/10.1089/g4h.2022.0214)] [Medline: [37294540](https://pubmed.ncbi.nlm.nih.gov/37294540/)]
8. Rehm IC, Foenander E, Wallace K, Abbott JM, Kyrios M, Thomas N. What role can avatars play in e-mental health interventions? Exploring new models of client–therapist interaction. *Front Psychiatry* 2016;7:186 [[FREE Full text](#)] [doi: [10.3389/fpsyt.2016.00186](https://doi.org/10.3389/fpsyt.2016.00186)] [Medline: [27917128](https://pubmed.ncbi.nlm.nih.gov/27917128/)]
9. Cerasa A, Gaggioli A, Marino F, Riva G, Pioggia G. The promise of the metaverse in mental health: the new era of MEDverse. *Heliyon* 2022 Nov;8(11):e11762 [[FREE Full text](#)] [doi: [10.1016/j.heliyon.2022.e11762](https://doi.org/10.1016/j.heliyon.2022.e11762)] [Medline: [36458297](https://pubmed.ncbi.nlm.nih.gov/36458297/)]
10. Melling B, Houguet-Pincham T. Online peer support for individuals with depression: a summary of current research and future considerations. *Psychiatr Rehabil J* 2011;34(3):252-254. [doi: [10.2975/34.3.2011.252.254](https://doi.org/10.2975/34.3.2011.252.254)] [Medline: [21208865](https://pubmed.ncbi.nlm.nih.gov/21208865/)]
11. Griffiths KM, Mackinnon AJ, Crisp DA, Christensen H, Bennett K, Farrer L. The effectiveness of an online support group for members of the community with depression: a randomised controlled trial. *PLoS One* 2012 Dec;7(12):e53244 [[FREE Full text](#)] [doi: [10.1371/journal.pone.0053244](https://doi.org/10.1371/journal.pone.0053244)] [Medline: [23285271](https://pubmed.ncbi.nlm.nih.gov/23285271/)]
12. Karyotaki E, Efthimiou O, Miguel C, Berman FMG, Furukawa TA, Cuijpers P, Individual Patient Data Meta-Analyses for Depression (IPDMA-DE) Collaboration, et al. Internet-based cognitive behavioral therapy for depression: a systematic review and individual patient data network meta-analysis. *JAMA Psychiatry* 2021 Apr 01;78(4):361-371 [[FREE Full text](#)] [doi: [10.1001/jamapsychiatry.2020.4364](https://doi.org/10.1001/jamapsychiatry.2020.4364)] [Medline: [33471111](https://pubmed.ncbi.nlm.nih.gov/33471111/)]
13. Crisp DA, Griffiths KM. Participating in online mental health interventions: who is most likely to sign up and why? *Depress Res Treat* 2014;2014:790457-790411 [[FREE Full text](#)] [doi: [10.1155/2014/790457](https://doi.org/10.1155/2014/790457)] [Medline: [24804089](https://pubmed.ncbi.nlm.nih.gov/24804089/)]
14. Batterham PJ, Calear AL. Preferences for internet-based mental health interventions in an adult online sample: findings from an online community survey. *JMIR Ment Health* 2017 Jun 30;4(2):e26 [[FREE Full text](#)] [doi: [10.2196/mental.7722](https://doi.org/10.2196/mental.7722)] [Medline: [28666976](https://pubmed.ncbi.nlm.nih.gov/28666976/)]
15. Knechtel LM, Erickson CA. Who’s logging on? Differing attitudes about online therapy. *J Technol Hum Serv* 2020 Oct 14;39(1):24-42. [doi: [10.1080/15228835.2020.1833810](https://doi.org/10.1080/15228835.2020.1833810)]
16. March S, Day J, Ritchie G, Rowe A, Gough J, Hall T, et al. Attitudes toward e-mental health services in a community sample of adults: online survey. *J Med Internet Res* 2018 Feb 19;20(2):e59 [[FREE Full text](#)] [doi: [10.2196/jmir.9109](https://doi.org/10.2196/jmir.9109)] [Medline: [29459357](https://pubmed.ncbi.nlm.nih.gov/29459357/)]
17. Klein B, Cook S. Preferences for e-mental health services amongst an online Australian sample? *EJAP* 2010 May 25;6(1):28-39. [doi: [10.7790/ejap.v6i1.184](https://doi.org/10.7790/ejap.v6i1.184)]
18. Rantanen T, Gluschkoff K, Silvennoinen P, Heponiemi T. The associations between mental health problems and attitudes toward web-based health and social care services: evidence from a Finnish population-based study. *J Med Internet Res* 2021 Sep 21;23(9):e28066 [[FREE Full text](#)] [doi: [10.2196/28066](https://doi.org/10.2196/28066)] [Medline: [34546184](https://pubmed.ncbi.nlm.nih.gov/34546184/)]

19. Philippe TJ, Sikder N, Jackson A, Koblanski ME, Liow E, Pilarinos A, et al. Digital health interventions for delivery of mental health care: systematic and comprehensive meta-review. *JMIR Ment Health* 2022 May 12;9(5):e35159 [[FREE Full text](#)] [doi: [10.2196/35159](https://doi.org/10.2196/35159)] [Medline: [35551058](https://pubmed.ncbi.nlm.nih.gov/35551058/)]
20. Borghouts J, Eikley E, Mark G, De Leon C, Schueller SM, Schneider M, et al. Barriers to and facilitators of user engagement with digital mental health interventions: systematic review. *J Med Internet Res* 2021 Mar 24;23(3):e24387 [[FREE Full text](#)] [doi: [10.2196/24387](https://doi.org/10.2196/24387)] [Medline: [33759801](https://pubmed.ncbi.nlm.nih.gov/33759801/)]
21. Wilson H, Hayward P, Donkin L. Will they or won't they? Understanding New Zealand adults' attitudes towards using digital interventions. *Front Digit Health* 2023 Mar 8;5:1008564 [[FREE Full text](#)] [doi: [10.3389/fdgth.2023.1008564](https://doi.org/10.3389/fdgth.2023.1008564)] [Medline: [36969957](https://pubmed.ncbi.nlm.nih.gov/36969957/)]
22. Dwivedi YK, Hughes L, Baabdullah AM, Ribeiro-Navarrete S, Giannakis M, Al-Debei MM, et al. Metaverse beyond the hype: multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *Int J Inf Manag* 2022 Oct;66:102542. [doi: [10.1016/j.ijinfomgt.2022.102542](https://doi.org/10.1016/j.ijinfomgt.2022.102542)]
23. Eysenbach G. Improving the quality of web surveys: the Checklist for Reporting Results of Internet E-Surveys (CHERRIES). *J Med Internet Res* 2004 Sep 29;6(3):e34 [[FREE Full text](#)] [doi: [10.2196/jmir.6.3.e34](https://doi.org/10.2196/jmir.6.3.e34)] [Medline: [15471760](https://pubmed.ncbi.nlm.nih.gov/15471760/)]
24. Prolific. Prolific. 2014. URL: <https://www.prolific.com> [accessed 2024-08-06]
25. Concato J, Peduzzi P, Holford TR, Feinstein AR. Importance of events per independent variable in proportional hazards analysis. I. Background, goals, and general strategy. *J Clin Epidemiol* 1995 Dec;48(12):1495-1501 [[FREE Full text](#)] [doi: [10.1016/0895-4356\(95\)00510-2](https://doi.org/10.1016/0895-4356(95)00510-2)] [Medline: [8543963](https://pubmed.ncbi.nlm.nih.gov/8543963/)]
26. Peduzzi P, Concato J, Feinstein AR, Holford TR. Importance of events per independent variable in proportional hazards regression analysis. II. Accuracy and precision of regression estimates. *J Clin Epidemiol* 1995 Dec;48(12):1503-1510 [[FREE Full text](#)] [doi: [10.1016/0895-4356\(95\)00048-8](https://doi.org/10.1016/0895-4356(95)00048-8)] [Medline: [8543964](https://pubmed.ncbi.nlm.nih.gov/8543964/)]
27. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. *J Clin Epidemiol* 1996 Dec;49(12):1373-1379. [doi: [10.1016/S0895-4356\(96\)00236-3](https://doi.org/10.1016/S0895-4356(96)00236-3)]
28. Vittinghoff E, McCulloch CE. Relaxing the rule of ten events per variable in logistic and Cox regression. *Am J Epidemiol* 2007 Mar 15;165(6):710-718. [doi: [10.1093/aje/kwk052](https://doi.org/10.1093/aje/kwk052)] [Medline: [17182981](https://pubmed.ncbi.nlm.nih.gov/17182981/)]
29. Brittan AS, Umaña-Taylor AJ, Lee RM, Zamboanga BL, Kim SY, Weisskirch RS, et al. The moderating role of centrality on associations between ethnic identity affirmation and ethnic minority college students' mental health. *J Am Coll Health* 2013 Apr;61(3):133-140 [[FREE Full text](#)] [doi: [10.1080/07448481.2013.773904](https://doi.org/10.1080/07448481.2013.773904)] [Medline: [25158010](https://pubmed.ncbi.nlm.nih.gov/25158010/)]
30. Yip T, Gee GC, Takeuchi DT. Racial discrimination and psychological distress: the impact of ethnic identity and age among immigrant and United States-born Asian adults. *Dev Psychol* 2008 May;44(3):787-800 [[FREE Full text](#)] [doi: [10.1037/0012-1649.44.3.787](https://doi.org/10.1037/0012-1649.44.3.787)] [Medline: [18473644](https://pubmed.ncbi.nlm.nih.gov/18473644/)]
31. Rogers LO, Meltzoff AN. Is gender more important and meaningful than race? An analysis of racial and gender identity among Black, White, and mixed-race children. *Cultur Divers Ethnic Minor Psychol* 2017 Jul;23(3):323-334. [doi: [10.1037/cdp0000125](https://doi.org/10.1037/cdp0000125)] [Medline: [27736104](https://pubmed.ncbi.nlm.nih.gov/27736104/)]
32. Hammer JH, Parent MC, Spiker DA. Mental Help Seeking Attitudes Scale (MHSAS): development, reliability, validity, and comparison with the ATSPH-SF and IASMHS-PO. *J Couns Psychol* 2018 Jan;65(1):74-85 [[FREE Full text](#)] [doi: [10.1037/cou0000248](https://doi.org/10.1037/cou0000248)] [Medline: [29355346](https://pubmed.ncbi.nlm.nih.gov/29355346/)]
33. Kroenke K, Strine TW, Spitzer RL, Williams JBW, Berry JT, Mokdad AH. The PHQ-8 as a measure of current depression in the general population. *J Affect Disord* 2009 Apr;114(1-3):163-173. [doi: [10.1016/j.jad.2008.06.026](https://doi.org/10.1016/j.jad.2008.06.026)] [Medline: [18752852](https://pubmed.ncbi.nlm.nih.gov/18752852/)]
34. Connor KM, Kobak KA, Churchill LE, Katelnick D, Davidson JRT. Mini-SPIN: a brief screening assessment for generalized social anxiety disorder. *Depress Anxiety* 2001;14(2):137-140. [doi: [10.1002/da.1055](https://doi.org/10.1002/da.1055)] [Medline: [11668666](https://pubmed.ncbi.nlm.nih.gov/11668666/)]
35. Fogliati VJ, Terides MD, Gandy M, Staples LG, Johnston L, Karin E, et al. Psychometric properties of the Mini-Social Phobia Inventory (Mini-SPIN) in a large online treatment-seeking sample. *Cogn Behav Ther* 2016 Apr 04;45(3):236-257. [doi: [10.1080/16506073.2016.1158206](https://doi.org/10.1080/16506073.2016.1158206)] [Medline: [27046641](https://pubmed.ncbi.nlm.nih.gov/27046641/)]
36. Seeley-Wait E, Abbott MJ, Rapee RM. Psychometric properties of the Mini-Social Phobia Inventory. *Prim Care Companion J Clin Psychiatry* 2009 Oct;11(5):231-236 [[FREE Full text](#)] [doi: [10.4088/PCC.07m00576](https://doi.org/10.4088/PCC.07m00576)] [Medline: [19956461](https://pubmed.ncbi.nlm.nih.gov/19956461/)]
37. Weeks JW, Spokas ME, Heimberg RG. Psychometric evaluation of the Mini-Social Phobia Inventory (Mini-SPIN) in a treatment-seeking sample. *Depress Anxiety* 2007;24(6):382-391. [doi: [10.1002/da.20250](https://doi.org/10.1002/da.20250)] [Medline: [17099878](https://pubmed.ncbi.nlm.nih.gov/17099878/)]
38. Schulenberg SE. The Development of the Computer Aversion, Attitudes, and Familiarity Index (CAAFI). PhD dissertation. Vermillion, SD: University of South Dakota; 2001.
39. Schulenberg SE, Yutrenka BA, Gohm CL. The Computer Aversion, Attitudes, and Familiarity Index (CAAFI): a measure for the study of computer-related constructs. *J Educ Comput Res* 2016 Jul 22;34(2):129-146. [doi: [10.2190/45b4-gmh7-geqb-t1h1](https://doi.org/10.2190/45b4-gmh7-geqb-t1h1)]
40. Schulenberg SE, Melton A. The Computer Aversion, Attitudes, and Familiarity Index (CAAFI): a validity study. *Comput Hum Behav* 2008 Sep 22;24(6):2620-2638. [doi: [10.1016/j.chb.2008.03.002](https://doi.org/10.1016/j.chb.2008.03.002)]
41. Fernández-Montalvo J, Peñalva-Vélez MA, Irazabal I. Internet use habits and risk behaviours in preadolescence. *Comunicar: Revista Científica de Comunicación y Educación* 2015 Jan 01;22(44):113-121. [doi: [10.3916/c44-2015-12](https://doi.org/10.3916/c44-2015-12)]
42. Uçak N. Internet use habits of students of the department of information management, Hacettepe University, Ankara. *J Acad Librariansh* 2007 Dec;33(6):697-707. [doi: [10.1016/j.acalib.2007.09.004](https://doi.org/10.1016/j.acalib.2007.09.004)]

43. Lanzieri N, McAlpin E, Shilane D, Samelson H. Virtual reality: an immersive tool for social work students to interact with community environments. *Clin Soc Work J* 2021 Mar 26;49(2):207-219 [FREE Full text] [doi: [10.1007/s10615-021-00803-1](https://doi.org/10.1007/s10615-021-00803-1)] [Medline: [33785971](https://pubmed.ncbi.nlm.nih.gov/33785971/)]
44. Lindner P, Miloff A, Zetterlund E, Reuterskiöld L, Andersson G, Carlbring P. Attitudes toward and familiarity with virtual reality therapy among practicing cognitive behavior therapists: a cross-sectional survey study in the era of consumer VR platforms. *Front Psychol* 2019 Feb 8;10:176 [FREE Full text] [doi: [10.3389/fpsyg.2019.00176](https://doi.org/10.3389/fpsyg.2019.00176)] [Medline: [30800086](https://pubmed.ncbi.nlm.nih.gov/30800086/)]
45. Bennett BL, Goldstein CM, Gathright EC, Hughes JW, Latner JD. Internal health locus of control predicts willingness to track health behaviors online and with smartphone applications. *Psychol Health Med* 2017 Dec 17;22(10):1224-1229 [FREE Full text] [doi: [10.1080/13548506.2017.1317354](https://doi.org/10.1080/13548506.2017.1317354)] [Medline: [28415852](https://pubmed.ncbi.nlm.nih.gov/28415852/)]
46. Werner P, Karnieli E. A model of the willingness to use telemedicine for routine and specialized care. *J Telemed Telecare* 2003 Jun;9(5):264-272. [doi: [10.1258/135763303769211274](https://doi.org/10.1258/135763303769211274)] [Medline: [14599329](https://pubmed.ncbi.nlm.nih.gov/14599329/)]
47. R Core Team. The R Project for Statistical Computing. R Foundation for Statistical Computing. 2023. URL: <https://www.R-project.org/> [accessed 2024-08-06]
48. Harrell FE. Ordinal logistic regression. In: *Regression Modeling Strategies*. Cham: Springer International Publishing AG; 2015:311-325.
49. Karyotaki E, Kleiboer A, Smit F, Turner DT, Pastor AM, Andersson G, et al. Predictors of treatment dropout in self-guided web-based interventions for depression: an 'individual patient data' meta-analysis. *Psychol Med* 2015 Oct;45(13):2717-2726 [FREE Full text] [doi: [10.1017/S0033291715000665](https://doi.org/10.1017/S0033291715000665)] [Medline: [25881626](https://pubmed.ncbi.nlm.nih.gov/25881626/)]
50. Schmidt ID, Forand NR, Strunk DR. Predictors of dropout in internet-based cognitive behavioral therapy for depression. *Cognit Ther Res* 2019 Jun 16;43(3):620-630 [FREE Full text] [doi: [10.1007/s10608-018-9979-5](https://doi.org/10.1007/s10608-018-9979-5)] [Medline: [32879540](https://pubmed.ncbi.nlm.nih.gov/32879540/)]
51. Gordon RA. *Regression Analysis for the Social Sciences*. 2nd ed. London, UK: Routledge; 2015.
52. Krippendorff K. *Content Analysis: An Introduction to Its Methodology*. 4th ed. Thousand Oaks, CA: SAGE Publications; 2018.
53. Cofie N, Braund H, Dalgarno N. Eight ways to get a grip on intercoder reliability using qualitative-based measures. *Can Med Educ J* 2022 May 29;13(2):73-76 [FREE Full text] [doi: [10.36834/comej.72504](https://doi.org/10.36834/comej.72504)] [Medline: [35572014](https://pubmed.ncbi.nlm.nih.gov/35572014/)]
54. ATLAS.ti Scientific Software Development GmbH. URL: <https://atlasti.com/> [accessed 2024-08-06]
55. Vaportzis E, Clausen MG, Gow AJ. Older adults perceptions of technology and barriers to interacting with tablet computers: a focus group study. *Front Psychol* 2017 Oct 04;8:1687 [FREE Full text] [doi: [10.3389/fpsyg.2017.01687](https://doi.org/10.3389/fpsyg.2017.01687)] [Medline: [29071004](https://pubmed.ncbi.nlm.nih.gov/29071004/)]

Abbreviations

- DMHI:** digital mental health intervention
MHSAS: Mental Help Seeking Attitudes Scale
Mini-SPIN: Mini-Social Phobia Inventory
MMHI: metaverse mental health intervention
OR: odds ratio
USC: University of Southern California
VR: virtual reality

Edited by T Leung; submitted 01.03.24; peer-reviewed by D Abdel-Hady; comments to author 06.07.24; revised version received 26.07.24; accepted 27.07.24; published 22.08.24.

Please cite as:

Ramos FN, Bernstein RA, Ezawa ID

Assessing Predictive Factors of Attitudes Toward Peer-Supported Mental Health Interventions in the Metaverse: Mixed Methods Study

JMIR XR Spatial Comput 2024;1:e57990

URL: <https://xr.jmir.org/2024/1/e57990>

doi: [10.2196/57990](https://doi.org/10.2196/57990)

PMID:

©Francisco Nicolas Ramos, Rachel A Bernstein, Iony D Ezawa. Originally published in JMIR XR and Spatial Computing (<https://xr.jmir.org>), 22.08.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR XR and Spatial Computing, is properly cited. The complete

bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Original Paper

Experience of Youths and Older People With Virtual Reality Games for Cognitive Assessment: Inductive Thematic Analysis and Insights for Key Stakeholders

Yesoda Bhargava¹, BTech, MTech, MPH; Veeky Baths¹, BSc, MSc, MBA, PhD

Cognitive Neuroscience Lab, Department of Biological Sciences, Birla Institute of Technology and Science, Pilani - K. K. Birla Campus, Goa, India

Corresponding Author:

Veeky Baths, BSc, MSc, MBA, PhD

Cognitive Neuroscience Lab

Department of Biological Sciences

Birla Institute of Technology and Science, Pilani - K. K. Birla Campus

NH 17B, Bypass, Road, Zuarinagar, Sankval

Goa, 403726

India

Phone: 91 9823764987

Email: veeky@goa.bits-pilani.ac.in

Abstract

Background: Virtual reality (VR)-based goal-oriented games for cognitive assessment are rapidly emerging and progressively being used in neuropsychological settings. These games have been validated quantitatively, but minimal qualitative insights from users currently exist. Such insights on user experience are essential to answering critical questions linked to the games' large-scale usability, adoption in hospital settings, and game design refinement. Current qualitative studies on these games have used general questionnaires or web-based reviews to answer these questions, but direct observation from primary settings is missing. We believe that direct observation of participants playing these games and subsequent interaction with them is critical to developing a more objective, clear, and unbiased view of the games' efficacy, usability, and acceptability.

Objective: In this study, we aimed to extract constructive and relevant insights directly from the participants who played VR-based goal-oriented games. We used these insights to answer vital questions linked to the practical utility of VR-based cognitive assessment. On the basis of these results, we also aimed to provide actionable insights to key stakeholders in the field, such as researchers, game developers, business personnel, and neuropsychology and allied professionals.

Methods: Interview data from 82 younger (aged 18-28 years) and 42 older adult (aged >60 years) participants were used. The interview data were obtained from the 2 pilot studies we conducted on VR games for cognitive assessment. Inductive thematic analysis was conducted on the interview data, and later, the findings were carefully interpreted to develop implications for the key stakeholders.

Results: We identified 5 themes: ergonomic issues, learning and training, postgame effects, game feedback, and system purpose. Regarding hardware, headset weight, adjustment straps, and controllers need to be improved to promote easy use of the device. Regarding software, graphics quality, immersion experience, and game mechanics are the primary deciding factors for a positive user experience. The younger group prioritized purpose and utility for long-term use, whereas the older participants cherished the entertainment aspect. Researchers and game developers must conceptualize and develop games that can provide maximum insights into real-world abilities. Manufacturing businesses need to improve the headset and accessories to make them more user-friendly. Finally, neuropsychology and allied practitioners must identify strategies to engage and train the participants to try VR-based cognitive assessment games.

Conclusions: VR-based games for cognitive assessment are promising tools to improve the current practices of neuropsychological evaluations; however, a few changes are required to make the overall user experience enjoyable, purposeful, and sustainable. In addition, all the key stakeholders need to focus on meaning and purpose over the hype of VR and are advised to work in synergy.

(JMIR XR Spatial Comput 2024;1:e59197) doi:[10.2196/59197](https://doi.org/10.2196/59197)

KEYWORDS

virtual reality; cognitive assessment games; inductive thematic analysis; youth; older adult; cognitive; cognitive assessment; virtual reality games; game; games; thematic analysis; neurological; utility; cognitive assessment tools; game based; cognitive games

Introduction

Background

Games for cognitive assessment have become very popular [1-6]. This development is motivated by the urgency for early detection of cognitive deficits such as dementia, which do not have a cure [7]. Moreover, traditional methods for cognitive assessment provide limited assistance for early detection of cognitive decline and fail to instruct about the real-world cognitive abilities of people [8-10]. In this context, goal-oriented games can serve as novel tools to address the gaps associated with traditional neuropsychological assessments [11].

Games for cognitive assessment can be either immersive or nonimmersive. The nonimmersive games are played on mobile-, tablet-, or computer-based platforms, whereas immersive games use virtual reality (VR) devices, usually a head-mounted display (HMD) and handheld controllers. Games in both the immersive and nonimmersive environments are effective for evaluating and assessing specific cognitive abilities such as memory, language, spatial abilities, and executive functioning and assist in stroke [12-15] and traumatic brain injury rehabilitation [16,17].

Of the 2 types of games, immersive games have generated a lot of excitement and enthusiasm among researchers, clinical personnel, and commercial enterprises [18]. The VR framework can create interactive and immersive 3D environments, which can simulate the real world. This simulation-based realism of VR environments is conducive to ecologically valid cognitive assessment [19-21]. In fact, VR games can assess the ability to carry out activities of daily living [22], detect visuospatial deficits [23-25], and assess cognition in general [26]. In addition to cognitive assessment, VR games are used for rehabilitation of executive functioning [27,28], memory impairment control [29-31], language improvement [32,33], and motor rehabilitation [34].

Clearly, VR games are useful for cognitive assessment and rehabilitation. Research studies have validated this usefulness through statistical and correlational analyses [22-24,35], and systematic reviews and meta-analyses also confirm the advantages [36-38]. However, quantitative validation is insufficient to deduce the acceptability and adoption of these tools in real-world neurological or medical settings. In fact, according to a qualitative study on 3 focus groups and 60 one-to-one interviews, the functional aspect of technology has little impact on its adoption [39].

Skewed focus on the quantitative validation of VR games exaggerates their functional aspects while completely ignoring the emotional, social, and epistemic aspects that are crucial to their adoption [40,41]. For a fuller validation of these games, it is essential to know users' attitudes toward them; the complexity they face during use; and the extent of compatibility

between the technology and their needs, values, and experiences. These factors can inform the perceived usefulness and ease of use of such VR games, ultimately indicating the likelihood of their adoption in the real world. The US Food and Drug Administration also advocates for qualitative evidence from key stakeholders on VR tools' relevance and significance [42].

While numerous reviews have established the impact of VR games for measuring and improving cognitive abilities such as executive functioning, spatial reasoning, memory, language, and attention, as well as activities of daily living [43], we still know very little about how users actually feel about these games. Therefore, to obtain perspectives beyond functionality in the context of VR games for cognitive assessment, studies that review and inform user experience and feedback are vital. Existing reviews in this context focus on web-based data [44-46], lack age-specific investigation [44-46], or simply focus on game design elements [47,48]. This lack of focus and direction from the user point of view is detrimental and fruitless to inform the acceptance and adoption of these tools in the real world.

In this context, we undertook this thematic analysis and distilled feedback on VR games for cognitive assessment obtained from 2 cohorts: 93 younger (aged 18-28 years) and 53 older (aged >60 years) participants. Data were obtained from 2 field trials conducted by us. The younger cohort was recruited from the Birla Institute of Technology and Science (BITS) Pilani K. K. Birla Goa Campus, and the older cohort was recruited from the Annasawmy Mudaliar General Hospital, Bangalore, India. All participants were cognitively healthy except for 2 in the older cohort who reported mild cognitive impairment.

Using thematic analysis, we extracted practical, applied, and insightful themes that inform about the strengths, challenges, and limitations of the VR games for cognitive assessment. We discussed the obtained themes and substantiated them through user comments. In a separate section for stakeholders, we discussed the implication of the findings for researchers, game developers, businesses, and medical settings. Our work is relevant to anyone who works at the forefront of using and developing VR games for cognitive assessment and rehabilitation.

In the next section, we present and discuss review studies on immersive and nonimmersive games for cognitive assessment. Later, we briefly describe the methodology used. Finally, the results are presented and discussed, followed by conclusions.

Literature Review

In this section, we briefly mention studies that quantitatively validate VR-based cognitive assessment games and acknowledge their importance for the translation of these games into the real world. Importantly, we also contrast the significance of qualitative studies on VR-based cognitive assessment games compared to these quantitative validation studies and develop

a case for the former's importance for real-world translation. Finally, we discuss previous qualitative studies on VR games and point out their limitations and contributions and, against this context, justify the significance of our work.

A meta-analysis of 18 studies found that healthy controls scored higher in games for executive functions, visuospatial abilities, and memory as compared to those with cognitive impairment [36]. Accordingly, the authors concluded that VR-based measures for cognitive processes are sensitive in detecting cognitive impairment. A different study established the criterion validity of the VR games for cognitive assessment using 5 factors of personality and convergent validity using scores of computer-based assessments [35], further validating the efficacy of VR-based cognitive assessment. However, the authors also pointed out the need to evaluate these games for their difficulty, adaption, autonomy, and control.

A systematic review of digital games for attention found that quantitative validation of game scores was primarily done against the traditional psychometric counterparts and clinical diagnosis [49] but the enjoyment properties of the games were rarely evaluated. In addition, a meta-analysis and systematic analysis that found VR games to be effective for rehabilitation of older adult patients after stroke remarked the importance of investigating game characteristics that drive positive changes in rehabilitation [37]. In the aforementioned studies, the authors sufficiently proved the validity of the VR games for cognitive assessment but also emphasized the need to examine the qualitative factors to obtain more clarity on the effectiveness and usability of these games. Clearly, there is a consensus among researchers on identifying and examining the factors associated with the wider adoption of these games. In fact, according to the theory of consumer research, knowledge of factors such as emotions, social value, and epistemic value is critical to sense user perception of a product's usefulness and adoption [40,41]. In this context, we discuss and critically analyze previous studies that inform our qualitative understanding of VR games.

A nonsystematic literature review on VR games for identification and rehabilitation of cognitive disorders reported nausea and disorientation among participants who played the games [50]. Although the authors described the games, the lack of specific insights into the game design and game elements precluded a deeper understanding of the causal factors for nausea and disorientation. Similarly, a narrative review of 29 papers on VR games summarized game designs used in VR game development [47]. However, we do not know how certain game designs are better or more effective than others for the usefulness and ease of use of VR games. On the other hand, a systematic review [48] found that score system and narrative context were the most popular game elements for neuropsychological assessment, training, and rehabilitation, but we do not know how the actual users feel about these popular game elements.

Each of these aforementioned reviews [47,48,50] is limited in its application to the real world as it is based on literature rather than direct user feedback. Although they provide a general understanding of game design, scores, game elements, and their aftereffects, reviews based on direct human experience and

feedback are preferable to inform the public-level acceptance and adoption of VR games for cognitive assessment. In fact, direct user opinions and feedback are crucial to ground the VR-based games for cognitive assessment and help separate practical utility from the VR hype [51-54]. To this end, we also discuss some studies that explore user feedback on VR games.

Analysis of 473 VR gamers' experience found that their use was primarily driven by enjoyment rather than usefulness [44]. Given that the sample comprised dedicated gamers, it is difficult to extrapolate these results to the general populace. Moreover, we do not know which types of games were played by these participants. Thus, even though the sample was large, its utility for reviewing the efficacy of VR games for cognitive assessment is precluded due to lack of information on the types of games played by the participants. Furthermore, the gamers were from different countries, and thus, cultural factors may be responsible for certain VR game preferences [55,56].

In a different study, web-based reviews of VR exergames sold in Steam, VIVEPORT, and Oculus were thematically analyzed, and it was found that realism, intuition, and skill enhancement were associated with positive user engagement, whereas a high number of bugs, poor graphics, and confusing control buttons were associated with user disengagement [45]. Similarly, a study on 1227 experienced VR gamers (6 months of experience) found that display quality, interactivity and service, enjoyment, and perceived control were indirectly linked to acceptance of and continuous intention to play the games [46].

The results of these 2 studies [45,46] provide a broad idea of qualitative aspects of VR games that are favorable and unfavorable for user acceptance, but because these studies are based on web-based reviews [45] and questionnaires [46], their impact is limited and lacks context required for real-world application and influence [52,53,57]. Consequently, it is difficult to discern from the aforementioned studies which features to continue with in VR game development, which to remove, and which to improve for cognitive assessment. To address this gap, it is vital to combine the findings of these reviews with direct feedback from participants in primary settings. Such direct feedback provides clearer information on user attitude toward the games, the challenges they face, and the perceived strengths of the game. Moreover, the opportunity to directly talk to the participants about their experience enriches the evidence base required to objectively establish the acceptance and adoption of VR games for cognitive assessment.

In summary, we observe that the existing evidence on validation of VR games for cognitive assessment is quantitative, lacks discussion and critical analysis of the context and content of the games, and is limited by lack of direct user feedback. Although existing quantitative evidence proves the functionality and potential of these games, it cannot be solely relied upon to indicate the acceptance and adoption of these games in real-world settings such as health centers for older people, old-age homes, neurological clinics, or even at home for individual assessment.

In this context, we present our thematic analysis, which is based on interviews conducted during 2 field trials on VR games for cognitive assessment undertaken by us. The games were

developed by us, and through these field trials, we obtained direct insights into the experience and feedback from youths (aged 18-28 years) and older participants (aged >60 years). The choice of a younger group was motivated by evidence of cognitive decline beginning in the third decade of life [58-72]. On the basis of the thematic analysis of the field trial data, we have richer insights into the user perception of VR games for cognitive assessment. We also present and discuss the implications of the findings for the key stakeholders in the field to foster real-world translation of the results, a practical goal that is missing in the aforementioned studies.

Methods

Overview

Our thematic analysis was based on the interview data we collected as part of our pilot on VR games among 82 younger participants (aged 18-29 years) and 42 older adult participants (aged ≥60 years). The youths were recruited from BITS Pilani K. K. Birla Goa Campus, and the older adults were recruited from the Annasawmy Mudaliar General Hospital, Bangalore, India.

In total, 2 VR games were piloted: a navigation game (Figure 1) and a hand-eye coordination game (Figure 2). The navigation game is an obstacle course game in which the participant has to wear the VR headset and use the handheld controllers to travel (walk and fly) through an animated virtual world course (land and sky), collect coins (rewards), identify turning points, and avoid obstacles to reach the final treasure (Figure 3). In the flying course, the participant uses controllers to fly and collect the coins in hoops suspended in the air.

In the hand-eye coordination game, the player is expected to hit blue cubes using a blue hammer (VR controller) and red cubes using a red hammer (Figure 2). The blue hammer is in the left hand of the player, and the red one is in the right hand.

A correct hit is registered when the red or blue cube is correctly hit by the red or blue hammer respectively in the direction specified on the incoming cube. Any other hit is incorrect. With every correct hit, the speed of the incoming cubes increases. Each participant played 3 trials of each VR game after playing a mini game that served as a tutorial for the actual game. An Oculus VR headset was used.

Both VR games were piloted in the younger group, but only the hand-eye coordination game was piloted in the older group due to the complex gameplay of the navigation game and the preliminary feedback of 2 older adults (aged >60 years). Before game administration, participants' basic level of proficiency with gaming, VR, and computers was obtained using a 5-point visual analog scale wherein 1 indicated the least experience and 5 indicated maximum experience. These data were important for contextual interpretation of game performance and feedback.

After game administration, feedback was obtained using 3 standard questionnaires: Virtual Reality Sickness Questionnaire [73], Virtual Reality Presence Questionnaire [74], and the System Usability Scale [75]. On the basis of the feedback from these 3 questionnaires, each participant was interviewed to obtain clarity on the context that guided their responses to the questionnaires. These interview data were used for the thematic analysis. The entire process took 1 hour for each participant.

Each individual comment was first coded to summarize its overall idea. Later, codes that were semantically similar were grouped together to form a theme. Themes were identified and later reviewed. Themes were categorized and named to reflect the codes they encompassed. In addition to the thematic analysis, we summarized the scores on the 3 questionnaires for each group. A statistical comparison between the groups was not possible because the older cohort did not play the navigation game. Finally, in a separate section, we discuss the implications of the findings for the key stakeholders in the field.

Figure 1. Navigation game sky view. The brown path and course can be seen, and the red and blue game elements indicate obstacles. The orange-colored hoops in the sky with suspended coins inside them illustrate the flying segment of the game.



Figure 2. Hand-eye coordination game first-person view. In total, 2 hammers can be seen (red and blue colored); each incoming cube has a direction arrow attached to it that indicates the desired motion of the hammer.

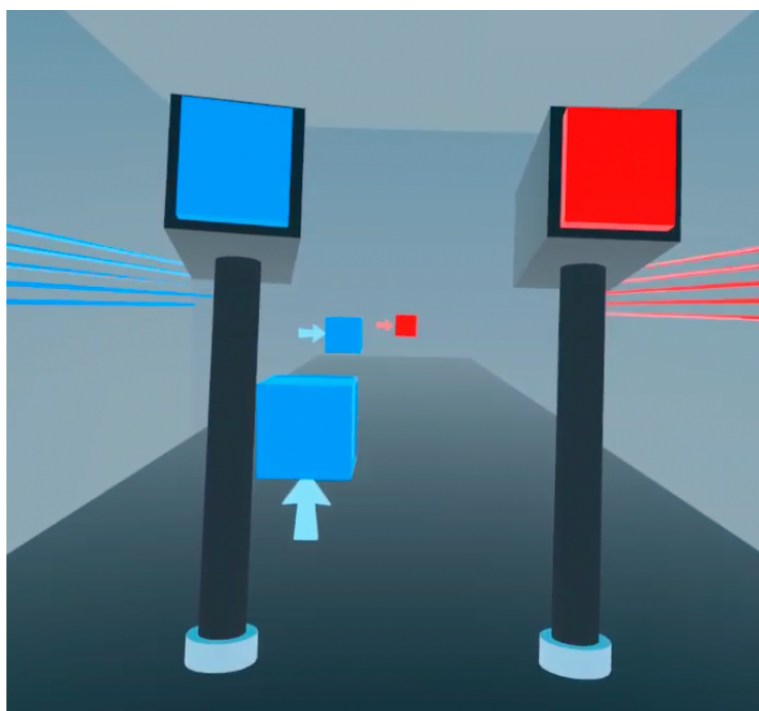
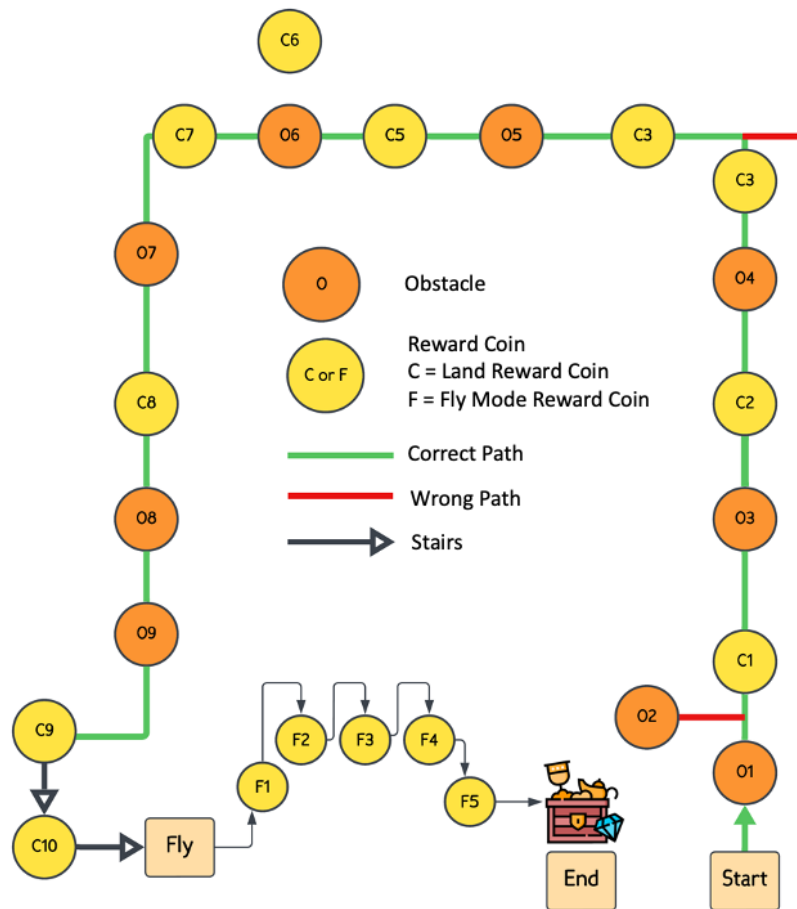


Figure 3. An abstraction of the virtual reality–based navigation game showing the obstacles, rewards (on the land and flying section), correct and incorrect paths, and the flying section.



Ethical Considerations

Written informed consent to take part in this study was provided by the participants. The procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975 as revised in 2008. All procedures involving human patients were approved by the Human Ethics Committee of BITS Pilani Goa Campus (reference HEC/BITS Goa/2023-2026). Ethics approval was also obtained from Annasawmy Mudaliar General Hospital separately for the recruitment and assessment of older adults.

Results

Overview

A total of 82 younger (mean age 20, SD 2.09 y; median age 20 y; $n=67$, 82% male) and 42 older (mean age 71, SD 6.31 y; median age 70 y; $n=26$, 62% female) participants took part in the study. In the younger group, most people (77/82, 94%) were right handed, 4% (3/82) were left handed, and 2% (2/82) were

ambidextrous. A total of 96% (79/82) of the participants were pursuing a graduate degree, and 4% (3/82) were pursuing a doctorate. Of the 42 older people, 30 (71%) were married, 8 (19%) were widowed, 3 (7%) were single, and the others' data could not be found.

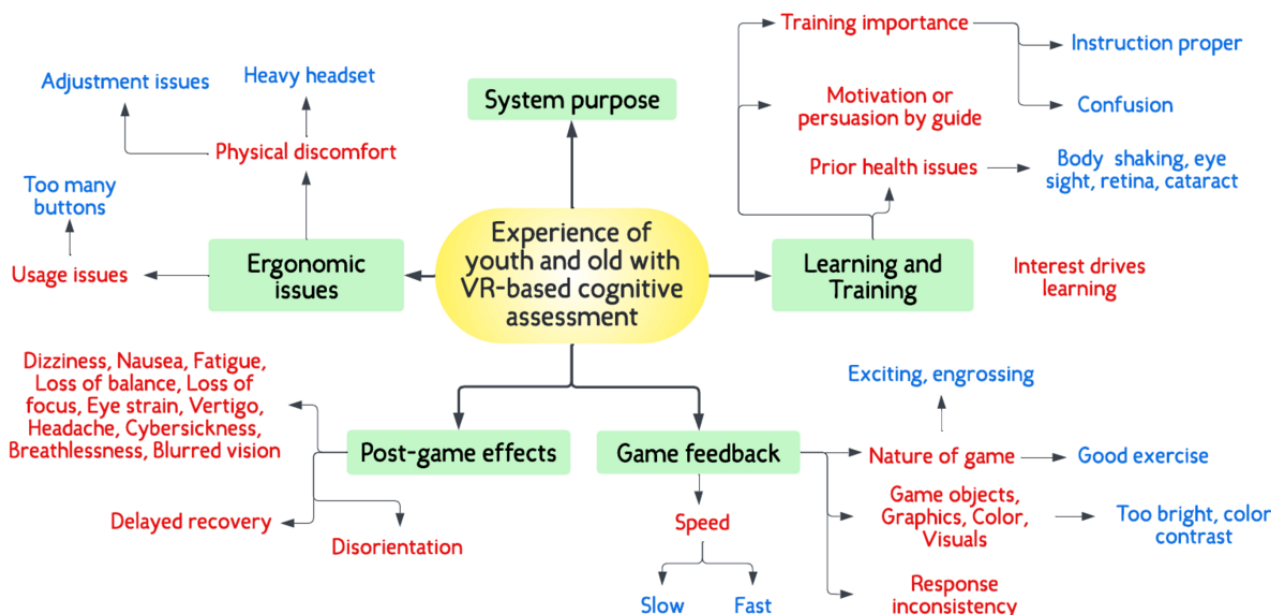
The results of the statistical comparison of the gaming, VR, and digital experience of the younger and older cohort are presented in Table 1. For all 3 measures, older people were less experienced than the younger ones. This was an expected observation as young people are relatively more aware of technology and gaming gadgets. However, strangely, the difference was lowest for VR experience. This small difference was due to the unfamiliarity of VR technology in both the younger and older groups. This comparison provides a context to interpret the results of the thematic analysis.

In total, 5 themes (Figure 4) were identified: ergonomic issues, learning and training, postgame effects, game feedback, and system purpose. We discuss each theme and substantiate it using examples from the data.

Table 1. Comparison of gaming, digital, and virtual reality (VR) experience of the older and younger cohort. Significance was assumed at $P < .05$.

Measure	μ_{old} (n=42)	μ_{young} (n=82)	Mean difference (95% CI)	P value
Gaming experience	2.85	4.06	-1.20 (-1.68 to -0.72)	<.001
VR experience	1.52	2.22	-0.695 (-1.10 to -0.293)	<.001
Digital experience	3.14	4.59	-1.45 (-1.86 to -1.04)	<.001

Figure 4. Thematic map showing the 5 themes and their subthemes. VR: virtual reality.



Ergonomic Issues

Most participants reported physical discomfort due to the VR headset or HMD. Older adults who had poor eyesight, retina problems, or cataract surgery history reported greater discomfort and uneasiness. The VR headset is an external device that is worn on the face covering the eyes and has 2 side straps for fixing or tightening the headset with respect to the head. The high weight of this headset (500 g) was the reason for this physical discomfort.

Our observations are substantiated by previous research that has found that the weight of the HMD and high local pressure lead to discomfort and fatigue and upset the user experience [76-79]. Previous research on use of VR HMDs for underground workers suggests that the maximum acceptable mass of the HMD is 1000 g [80], but in our study, we found that participants complained of heaviness in the headset even though its weight was 500 g.

The heaviness of the headset caused discomfort during the hand-eye coordination game in both the younger and older cohorts. We believe that this discomfort was aggravated by the physical movement of hands and limbs required in the hand-eye coordination game because similar discomfort was not reported for the navigation game, which does not require any physical movement. Thus, it appears that games that require passive engagement would be more tolerable with the current weight of the headset. However, such passive engagement is not conducive to realistic cognitive assessment because real-world tasks require movement and action. Therefore, the heaviness of

the headset is detrimental to the long-term adoption and acceptance of VR-based cognitive assessment games in the general populace [77,79].

It was also found that the side straps provided with the commercial headset are not user-friendly and using them for fixing and adjusting the headset is inconvenient. The issue of adjustment of straps was reported in the younger cohort, in whom the pilot was conducted first. On the basis of their feedback, we replaced the original adjustment straps with the enhanced side-strap support provided by the KIWI design. This change improved the head adjustment for the older group, and no adjustment problems were reported in this cohort. Our observation on the original adjustment straps provided with the Oculus headset is confirmed by an opinion piece by a law, technology, and human rights attorney [81]. The author mentioned that the strap adjustment piece keeps pulling out when adjusting for different participants and is difficult to fit around traditional headgears such as turbans and hijabs.

In addition to the headset and strap problems, participants reported issues related to button use in the handheld controllers. Each Oculus handheld controller has a total of 6 buttons. The index finger is generally put on the trigger button, the middle finger is put on the gripper, and the thumb is used to control the other 4 buttons. Although the game instructions notify the use of the buttons, the participants still reported confusion with button use at runtime. Particularly in the navigation game, participants reported confusion as the game involved multiple buttons: walking, stopping, and flying. The controller buttons

do not seem naturalistic to real-world use, and some researchers indicate that VR gloves are superior [82].

However, for the hand-eye coordination game, which did not require any buttons to be pressed on the controllers, this confusion was not reported, but a peculiarity was observed wherein older people assumed that they needed to press the button to play the game. It took some time to make them realize that only controller movement was required and no buttons on the controller needed to be pressed. However, ideally, in such games, it is better to use controllers that do not have buttons.

VR gloves could appear more intuitive and naturalistic as they lessen the abstraction between the real and virtual worlds [82].

Textbox 1 shows some comments from the participants that substantiate the ergonomic issues with the headset.

Due to both the heavy headset and multiple buttons on the controllers, the participants could not seamlessly play the games. To address this, device manufacturers need to minimize the headset weight, and game developers can use the buttons on the controllers that are intuitive and aligned with natural finger use in day-to-day life.

Textbox 1. Comments from the participants on the theme of ergonomic issues.

Youths

- “People with high power in specs, may find some discomfort initially.” [Male and female participants; aged 18-21 years]
- “Headset was heavy.” [Male and female participants; aged 18-26 years]
- “Making turns in the Navigation game using controllers was not very friendly.” [Male and female participants; aged 18-21 years]
- “I had fullness of head due to the headset.” [Male and female participants; aged 19 years]
- “Too many buttons in the controller.” [Male participant, aged 18-19 years, and female participant, aged 26 years]
- “I had headset adjustment issue, due to which I had blurred vision. With spectacles, it was an added difficulty.” [Male and female participants; aged 22, 23, and 26 years]

Older people

- “I had a feeling of interference due to glasses. Without glasses, it was difficult as the headset was very heavy.” [Male participant; aged 62 years]
- “Difficult for everyone, would like to use only the computer frequently, but not the VR.” [Female participant; aged 64 years]
- “Could not play the VR Game as experienced discomfort on putting the headset. I also have retina issues so I do not want to play the game.” [Male participant; aged 69 years]
- “First time holding it, so I am very conscious and find it difficult to use.” [Female participant; aged 71 years]
- “I found the headset very heavy, and without glasses also I found it difficult.” [Female participant; aged 75 years]

Learning and Training

The second theme related to the learning and training required to play the VR-based games. Given that the VR-based experience was novel for both the younger and older groups (VR experience=1.52/5 for the older cohort and 2.22/5 for the younger cohort), learning and training is crucial. A difficult learning process and poor training might dissuade users from adopting the technology.

In our study, training was provided using a short tutorial for the VR games and controller use. Each participant had a chance to play a mini game before playing the 3 trials for each game. The mini game served as a hands-on training for the games. Both younger and older participants acknowledged that the training helped them play the games independently. Few complained of not understanding the video instructions due to audio and background noise. In these cases, extra explanations were provided, but it is essential to eliminate audio and noise from the training and learning videos. Due to playing 3 trials, the participants were able to gradually learn how to play the games.

We also realized that, in the context of VR, training must not be limited to technology-based training. For older people, training can be augmented by explanation, support, and persuasion from the game administrator. These game

administrators could be neuropsychologists, neurophysiotherapists, or neuropsychiatrists. For example, in our study, a male participant aged 73 years could not understand how to play the hand-eye coordination game despite repeated instructions. His recent cataract surgery caused him difficulty to apply the instructions to the game. However, with the patience and support of the game administrator, combined with his interest, he was able to successfully learn how to play the game independently.

However, sometimes, repeated assistance may not work if the patient has cognitive impairment. For example, in our study, a male participant aged 62 years with mild cognitive impairment kept forgetting the instructions during the game, so it was challenging to sustain learning due to his medical condition, impeding his gameplay. Therefore, according to the context, the situation, and the interest of the participant, learning and training can be customized for unique cases.

In the existing literature, very few studies have focused on the learning or training required to play VR games. We found research on using VR games for learning and teaching in academic settings [83,84], but research on the difficulty or ease of learning to operate VR and play games on it is missing. Existing studies on VR focus on its usability [85], perception [86], and adoption [87] but fail to comment on the learning and

training required to use it. The learning trajectory of VR is important to study in different population groups at whom the products are targeted, especially the older adult group.

[Textbox 2](#) shows comments from the participants to substantiate the aforementioned discussion.

From the comments in [Textbox 2](#), it is clear that youths reported fewer challenges with learning and training for the VR games and the older group faced difficulties. This difference can be attributed to aging effects on learning [88]. Accordingly, solutions and strategies need to be developed to cater to the unique learning needs of the older population.

Textbox 2. Comments from the participants on the theme of learning and training.

Youths

- “Tutorial was enough, games were easy.” [Male participant; aged 18 years]
- “Technical for first-timers.” [Male participant; aged 19-20 years]

Older group

- “Something out of routine, so found it difficult.” [Female participant; aged 65 years]
- “The introduction video voice is not clear.” [Female participant; aged 67 years]
- “The instructions in the video were fast.” [Male participant; aged 73 years]
- “The confusion was there for the first two times, later it became clear.” [Male participant; aged 73 years]
- “Was confused in the beginning, as it had been a long time.” [Female participant; aged 65 years]
- “Except for few things in the beginning, it was easy to learn.” [Female participant; aged 69 years]
- “If the person is interested, they will learn quickly.” [Male participant; aged 73 years]
- “Overall, the games were extraordinary. The guide who conducted the test was in a position to articulate well for my understanding and performance.” [Male participant; aged 72 years]

Postgame Effects

Both the younger and older cohorts reported immediate but subsiding health-related effects after the VR games. This included dizziness, nausea, fatigue, eyestrain, vertigo or headache, cybersickness, breathlessness, blurred vision, loss of balance, loss of focus, and disorientation. Participants with previous health issues such as screen strain reported relatively higher eyestrain after the VR game.

Due to these health effects, participants took some time to become comfortable after the games, normally 30 to 60 seconds, as we observed. The postgame discomforting effects were more commonly reported after the navigation game. These effects could be attributed to the nature of the navigation game, which requires no physical movement. Thus, the player has a perception of forward motion or flying (in the flying segment) in the game while they are actually standing or sitting in the real world. Due to this sensory discrepancy, there is a sense of inertia during the game and disorientation after the game. This sense of inertia seemed to have compounded over the 3 continuous trials of the navigation game, resulting in postgame disorientation and negative health-related effects.

For the hand-eye coordination game, postgame health effects were minimal in the younger and older cohorts. Unlike the navigation game, wherein a sensory discrepancy is present between the player in the game and the one in the real world, in the hand-eye coordination game, this is not so. The movements of hand and limbs expected in the hand-eye coordination game are aligned with the movement in the real world; consequently, there is no sense of disconnection experienced by the player during the game. Therefore, postgame

effects such as dizziness, nausea, and disorientation were not observed for the hand-eye coordination game. Still, tiredness and fatigue among the older group were reported, which were indicative of their physical movement during the 3 trials of the game and may not necessarily be negative.

A core reason for the postgame effects of the VR games could be the continuous administration of 3 trials. Continuous VR exposure, especially to the graphic-rich and stimulating environment of the navigation game, can intensify the negative postgame effects [89,90]. Adverse health effects after VR exposure are well documented in research. Our findings are confirmed by previous research that reports cybersickness characterized by visual fatigue, headache, disorientation, dizziness, nausea, and tiredness [91-97]. In scientific terms, these are referred to as VR-induced symptoms and effects [98]. For a detailed study of VR-induced symptoms and effects, readers can refer to the narrative review by Souchet et al [99].

In [Textbox 3](#), we substantiate the postgame effects using comments from the groups. Among the youth, all the comments on postgame effects were related to the navigation game.

Comments from the older cohort are shown in [Textbox 4](#). We noticed very few complaints of postgame adverse health effects among the older group. This is attributed to the gameplay of the hand-eye coordination game, in which no sense of disconnection or discrepancy was experienced by the player in the virtual world and the real world.

From the aforementioned discussion and examples, it is clear that sensory discrepancy or too much stimulation and continuous exposure can lead to negative postgame effects, which normally subside after some time and are not dangerous. Still, these

effects may be detrimental to the acceptance of VR games and need to be minimized.

Textbox 3. Comments from the younger participants on the theme of postgame effects.

Youths

- “Eye strain due to color in the Navigation game.” [Male and female participants; aged 18-23 years]
- “Eye strain due to headset.” [Male and female participants; aged 19-23 years]
- “Skeptic of the vision problems caused by VR.” [Male participant; aged 19 years]
- “Exhausted after the Navigation game.” [Male participant; aged 19 years]
- “Experience just like post exam—got tired.” [Male participant; aged 19 years]
- “Lost balance many times in the Navigation game.” [Male and female participants; aged 19-21 years]
- “Sense of balance is lost while in the game, headset is heavy. Reported nausea, disorientation. In the second trial removed the headset once, 3rd trial not played. Asked to be seated and play, but reported discomfort and quit.” [Male participant; aged 21 years]
- “Navigation game was disorienting a bit.” [Male participant; aged 19 years]
- “Headache, eye strain, blurry vision due to heavy usage (by the end of Trial III).” [Male and female participants; aged 18-21 years]
- “Headache during post-game form filling.” [Male participant; aged 19-20 years]
- “Initially in the beginning headache was there, improved with time.” [Male participant; aged 18 years]
- “Little dizziness in the beginning.” [Male and female participants; aged 18-19 years]
- “Dizziness is a put-off.” [Male and female participants; aged 18-21 years]
- “Head feels more heavy after the movement game and during turning motions.” [Male and female participants; aged 18-21 years]
- “Head spinning during the fly.” [Male participant; aged 19 years]
- “Cannot play for longer time.” [Male participant; aged 20 years]
- “After the game, took time to come back to the real world.” [Male participant; aged 18 years]
- “Takes time to get normal.” [Male participant; aged 19 years]
- “After the games, difficulty in walking in the real world. Could not walk in a straight line after the game.” [Male participant; aged 19 years]

Textbox 4. Comments from the older participants on the theme of postgame effects.

Older group

- “Eye strain after playing and headache.” [Female participant; aged 64 years]
- “Played only two levels of the VR game, got very tired after two trials, so wanted to stop.” [Male participant; aged 67 years]
- “Could not play the VR game as she felt dizzy.” [Female participant; aged 75 years]
- “I felt very tired and breathless and wanted to stop after the 1st level but was persuaded to try, but again I got breathless after the 2nd level.” [Female participant; aged 75 years]

Game Feedback

The game feedback differed for the 2 VR games. Most of the younger participants highlighted that the graphics in the navigation game were too bright and had high contrast. Previous research on VR games has also identified color and contrast as important factors for VR games and linked them to cybersickness [76,94]. Poor graphics such as frequent color change and highly dynamic videos are linked to visual fatigue in VR games [100,101].

When inquired about the realism of the game, participants remarked that the game objects were animated and seemed unreal. We realized that the younger participants defined game realism strictly based on its overlap with the real-world environment and objects. Although this expectation is not unjustified, we believe that it imposes a very rigid definition of

realism in the context of VR. On reflection, we realized that realism in the context of VR is a broader concept and may include real-world scenarios, but this criterion is not necessary to establish the realism of VR games. Animated game environments that mimic the nature and intensity of cognitive load observed in the real world also hold realism. Accordingly, even if the objects in the animated game environment do not duplicate real-world objects, if they can assess cognitive processes and skills similarly to real-world cognitive engagement, such animated game environment has realism. From this broader standpoint on realism, we believe that the navigation game held realism as it involved cognitive processes linked to walking, avoiding obstacles, waiting, climbing stairs, and grasping.

Realism in VR has been found to be associated with greater presence and more intense responses [102,103] and is one of the factors that determine enjoyment. Thus, it is important to consider it when designing games for cognitive purposes.

Textbox 5 presents some comments from the younger group on game feedback.

For the hand-eye coordination game, color or graphics issues were not reported by any of the group participants. In fact, a female participant aged 69 years shared that she was deeply involved in the visuals of the hand-eye coordination game. However, participants pointed out a mismatch and inconsistency between user action and game responses. Both younger and older participants complained that their hammer hits were not registered at times, due to which they lost key points. Participants also reported latency in the response to their actions, which caused lagging in the game. Both latency and lagging are known factors that relate to VR experience; however, it is believed that these are hardware issues and are less likely to occur with new HMDs [76].

Furthermore, in the older group, we found mixed reviews on the speed of the incoming cubes in the hand-eye coordination game. Some participants felt that the speed was higher, due to which they could not focus on both the colored cubes, whereas a few felt that it was too slow and could be increased. These 2

Textbox 5. Comments from the younger participants on the theme of game feedback.

Youths

- “HD Graphics could improve the user experience.” [Male participant; aged 18 years]
- “Graphics did not seem natural.” [Male participant; aged 18 years]
- “Cartoonish visual aspects, knew they were fake.” [Male participant, aged 19 years, and female participant, aged 21 years]
- “Colors were too bright, too many things were moving.” [Male and female participants; aged 18-19 years]
- “Lot of stimulus was there.” [Male participant; aged 19 years]
- “Interaction with the environment was not realistic.” [Male participant; aged 19 years]
- “Photorealism is lacking.” [Male participant; aged 19-21 years]
- “Graphics not that good, color saturation unlike the real world in the Navigation game.” [Male participant; aged 22 years]

contrasting views indicate subjectivity in the perception of the game but also call for dynamic adjustment of the speed of incoming cubes. Such enhancement could greatly improve the user experience of the game. Moreover, given the frailty in the older group, we also noticed that the hand-eye coordination game could be made more flexible by introducing a seated gaming arrangement.

Finally, our broader definition of realism was also confirmed in the hand-eye coordination game, wherein participants reported that the game felt natural and real. Even though no one plays such a game in the real world, the movements, such as lifting a hammer and moving it sideways, up, and down, are typical of the real world. A sense of sensory synergy (ie, similar movements in the real and virtual world during gameplay) also contributed to a sense of realism in the hand-eye coordination game. Our views on realism in the VR games are confirmed in a research paper that calls for deeper understanding of realism and mentions that it relates to both the illusion and immersion components [104]. Thus, a multisensory environment could be more immersive as it engages the senses of the person just like the real world.

Textbox 6 presents some of the comments on the hand-eye coordination game from the older cohort that substantiate this theme.

Textbox 6. Comments from the older participants on the theme of game feedback.

Older cohort comments on the hand-eye coordination game mechanics

- “Getting annoyed, sometimes, even when hitting correct, it did not smash. The logic of cube hitting was not consistent for all the cubes.” [Female participant; aged 68 years]
- “The speed was so fast it required to be fast, but that was causing confusion.” [Male participant; aged 73 years]
- “The incoming cubes were too fast, and sometimes when it is left and other is coming at the right, it is difficult to move fast.” [Male participant; aged 68 years]
- “When the game is slow, it is ok, but not when it is fast.” [Male participant; aged 78 years]
- “As soon as I hit red, blue came fast, that’s why I lost so many points. Felt like brain was not acting properly when using two hammers.” [Male participant; aged 73 years]
- “Needed practice, left hand not as fast as the right so took time to be fast.” [Female participant; aged 67 years]
- “The cube could move faster, as it is giving time to think, could be challenging if it moved faster.” [Male participant; aged 77 years]
- “Difficult to coordinate with both the hands, one hand is better.” [Female participant; aged 65 years]
- “As level increases, complexity should be high so that it is interesting and keep the user hooked.” [Male participant; aged 74 years]
- “Was very enjoyable, did not feel like it was a test.” [Female participant; aged 67 years]

Older cohort comments on the hand-eye coordination game in general

- “Interesting experience, hand fun. No changes required, good as it is.” [Female participant; aged 63 years]
- “The coordination was a good exercise.” [Female participant; aged 63 years]
- “The game was fun and the music in the game was fun.” [Female participant; aged 68 years]
- “Very much liked it. Nothing was distracting.” [Female participant; aged 69 years]
- “It was a good experience.” [Male participant; aged 74 years]
- “Because the game is artificial environment, it will look artificial.” [Female participant; aged 63 years]
- “If there is an option to let you sit and play, then that would be good.” [Female participant; aged 71 years]

System Purpose

Both younger and older participants were curious about the purpose of the VR games. At the beginning of the trial, we informed the participants about the games, how to play them, and how participant performance would be mapped to their cognitive abilities or performance. This explanation and training were aimed at making them aware of the subsequent game-*cum*-assessment sessions. After the session, participants were more inquisitive about these games having experienced them directly.

Indeed, the purpose or utility of VR games for users is important because they need to decide whether to accept them for their hedonistic or utilitarian purposes [52,53]. In fact, in the initial stages, the excitement and novelty drove their participation, but going forward, the system’s purpose would define the continuous engagement with the games. Therefore, the system’s purpose is a very important theme in the context of VR-based cognitive assessment games. The purpose indicates the perceived usefulness, which eventually influences their adoption as per the technology acceptance model [105].

A meaningful purpose engenders a positive attitude among the users and key stakeholders and determines the long-term

adoption of VR games [106,107]. Thus, after the initial excitement and hedonistic pleasure has plateaued, VR-based games will have to prove their efficacy [57], and a clear purpose can accomplish this.

Textbox 7 shows comments to substantiate the theme of system purpose.

In the older group, no one inquired about the system purpose. It appears that, for them, engagement and an opportunity to try something new were more valuable than purpose, and similar findings have been obtained previously [108-111]. This perspective is advantageous to develop more engaging, active games in the VR environment for older people, especially for rehabilitation and skill building. Thus, a trade-off between utilitarian and hedonistic motives was observed in the 2 groups. Key stakeholders must maneuver their strategies to serve these differential motives.

We have discussed in detail the 5 prominent themes that were identified by analyzing the interview responses of the younger and older groups. We understand the importance of linking these findings to real-world actions and decisions; thus, in the next section, we discuss the implications of the results.

Textbox 7. Comments from participants on the theme of system purpose.

Youths

- “I do not know what the system is for as of now. I do not know why I would use it.” [Male participant; aged 19 years]
- “Not sure what the system is aimed at.” [Male participant; aged 18 years]
- “I won’t use it on a daily basis. Once or twice a week.” [Male participant; aged 20 years]

Implications of the Results

In this section, based on the results of the thematic analysis, we provide precise actionable suggestions relevant to 4 key stakeholders: researchers, game developers, businesses, and neuropsychology and allied practitioners.

Researchers

From the results of the thematic analysis, it is evident that all participants were eager to engage with the VR-based games. To translate this initial eagerness into long-term engagement, researchers need to identify gaming concepts, designs, environments, and abstractions that can be used for developing cognitively stimulating games. Given the limitation of ecological validity in the traditional pen-and-paper-based neuropsychological assessments [8-10,112-114] and the comments on game realism by the participants, researchers can design gaming ideas that resemble real-world situations and mimic the cognitive load and decision-making required for real-world tasks. Such an approach could potentially provide more informed assessment of the real-world-relevant cognitive abilities and deficits of the person. To this end, interaction with customers and brainstorming with other researchers in the fields of neuroscience, computer science, customer satisfaction, and human psychology is essential [115,116].

Game Developers

Game developers are often excited about the special effects, high-end graphics, and engaging music that make their games unique. However, in the context of cognitive assessment and rehabilitation, simplicity and intention are key factors that game developers must remember. In the navigation game, button use, graphics, and multiple stimuli caused a lot of confusion and adverse postgame effects, due to which the overall experience was less enjoyable. On the other hand, the hand-eye coordination game was simple, intentional, and very intuitive; consequently, both the younger and older cohorts enjoyed the overall experience. Taking a cue from these findings, game developers must prioritize simple and intuitive gameplay for cognitive engagement. This approach would create games that can flow on their own while engaging the player. This sense of flow is important for the players as it is linked to intention to use [117-120]. Bad graphics, bugs, overstimulated environments, and response-feedback inconsistency can lead to loss of flow and discomfort [45,73,121]. Therefore, game elements must be designed to promote a natural flow in the game. Knowledge of such elements and their quality can be obtained through regular testing among the target users.

Businesses

Recently, several business enterprises centered on cognitive assessment and rehabilitation have emerged. To truly have an

impact on the lives of people, these enterprises need to focus on some key takeaways from this thematic analysis. The most important takeaway is purpose and meaning. While the technology and game thrill may excite the players momentarily, meaning and the long-term impact of the game will lead to sustainable adoption.

Especially among the younger group, game utility determines adoption. However, in the case of the older group, entertainment and enjoyment seem to have an edge over utility. Still, we believe that the 2 do not have to be mutually exclusive. Both utilitarian and hedonistic aspects can be integrated in cognition-assessing games. For example, our hand-eye coordination game was both useful and enjoyable, and its feedback from both groups was very positive.

Second, manufacturing businesses need to rethink the VR headset and controller design [122,123]. The current weight of the VR headset [124,125] and the adjustment straps can cause issues such as fatigue, headache, and discomfort. Therefore, lightweight HMDs and integrated headsets such as the one with KIWI support are better than soft band straps [124]. In addition, controller buttons must be designed to minimize interference and confusion in use; this improvement would lead to more intuitive use of the controllers, promoting flow in the game [118,119]. Thus, the ergonomic issues directly relate to HMD manufacturers and motivate them to make human-centered design decisions [126-128].

Neuropsychology and Allied Practitioners

VR-based games for cognitive assessment and rehabilitation are often used in neuropsychological clinics or laboratories. Findings of our thematic analysis are also relevant to practitioners in these settings. The learning and training theme results emphasize using quality instructions for communicating and demonstrating the game rules. In case audio and video instructions do not suffice, facilitators can explain the instructions to the patients. Our results also demonstrate the positive impact of motivation and persuasion on the patients when they have qualms or apprehension about the games. Neuropsychology practitioners must also be mindful of previous health issues of the patients while administering games to them. Thus, an element of compassion and kindness, not amounting to infantilizing or spoon-feeding, is essential while administering the games, especially in the older cohort.

Tabulated Summary of the Theme and Their Relevance to Key Stakeholders

The applicability of the theme results to different sectors were tabulated (Textbox 8). It is clear that most of the themes are relevant to all stakeholders. Thus, all 4 key stakeholders must

work in synergy to innovatively use VR technology for cognitive assessment and rehabilitation.

Textbox 8. Themes and the stakeholders directly or indirectly linked to them.

Theme and applicability sector or stakeholders

- Ergonomic issues: hardware manufacturers and businesses
- Learning and training: game developers, businesses, researchers, and neuropsychology and allied practitioners
- Postgame effects: game developers, businesses, researchers, and neuropsychology and allied practitioners
- Game feedback: game developers, researchers, and neuropsychology and allied practitioners
- System purpose: game developers, businesses, researchers, and neuropsychology and allied practitioners

Discussion

Principal Findings

In our study, we found that most of the problems faced by the participants were due to headset weight, adjustment straps, game graphics, or motion in the game. Several previous reviews on VR games discuss and describe these challenges associated with VR games but fall short of investigating the reasons behind them [47,48,50]. Such a limited approach does not contribute to improved user experience because we do not know which things to mend and which features to continue with. Furthermore, VR technology is touted to disrupt the health care service sector; therefore, it is crucial that direct human feedback is obtained because any other secondary means, such as literature reviews and web-based reviews [45], risk half-truths.

We also found that different users have different reasons to adopt the product. While both the younger and older cohorts attested to the entertainment and excitement part of it (ie, the hedonistic aspect of the game), the younger group also expressed curiosity about its use and purpose. Previous studies exploring the hedonistic [44] versus utilitarian aspects [48] of VR games provide a general description of these but do not comment on who may be more inclined toward the hedonistic or utilitarian aspects. From our study, we observed that older adults may be more attracted to the hedonistic aspect of the game, whereas the youth may be lured by it temporarily and anticipate utility in the long run. We believe that this insight is extremely useful for evidence-based translation of cognition-assessing VR games.

Our findings on issues of bugs, highly saturated graphics, and confusion due to multiple controller buttons are substantiated by a thematic analysis based on web reviews [45]. Concerns about realism, display quality, and game interface found in our work form the most prominent aspects of VR-based research [46]. Overall, our findings are confirmed by existing research on VR games. However, unlike previous studies that merely report the concerns and advantages of VR-based games, we have raised questions that emphasize the importance of uncovering the causal factors behind these concerns and advantages. Ultimately, the knowledge of these causal factors paves the road for improved experiences with VR game-based cognitive assessment.

Especially with a novel technology such as VR, there is a lot of responsibility on all the stakeholders as there is a risk of addiction [129] and adverse effects [130]. Our discussion on

the implications of the study for the stakeholders will indirectly help with the improvement of VR games, thereby assisting in enhanced cognitive assessment and rehabilitation. However, it must be remembered that novel technology tools must be handled with a sense of accountability wherein user interests and safety are superior to commercial interests.

Conclusions

We presented a thematic analysis of the interview responses of 82 younger (aged 18-28 years) and 42 older (aged >60 years) participants after they played VR-based cognitive assessment games. A total of 5 main themes were identified and discussed: ergonomic issues, postgame health effects, game feedback, learning and training, and system purpose. We found that the younger and older groups had different needs and expectations from these games. For long-term engagement, the younger group prized meaning and utility, whereas the older group liked the enjoyment and entertainment aspects. We also found that the heaviness of the headset, cybersickness, and visual fatigue are the most common problems faced in both groups. However, these problems are less painful if the game environment is not hyperstimulating and has warmer color graphics. In addition, games with less conflict between the real-world sensory information and the VR environment movement are more enjoyable than those with sensorimotor conflict.

We also discussed the implications of these themes for 4 key stakeholders in the field: researchers, game developers, businesses, and neuropsychology and allied practitioners. Researchers must identify real-world concepts that can be used to design ecologically valid games that engage the senses and cognitive abilities similarly to the real world. Game developers need to develop games that are simple, intentional, exciting, and able to flow on their own. Business enterprises must focus on giving a purpose and meaning in these cognitive assessment games to ensure long-term use and impact. Manufacturing businesses must address the issues related to the heaviness of the headset, unfriendly side adjustment straps, and multiple controller buttons to simplify the use experience during assessment. Finally, neuropsychology and allied practitioners play the most important role of administering the VR-based games to the patients and, thus, must be willing to explain these games to patients and use persuasion and compassion during the process. Finally, all stakeholders must collaborate together to develop high-impact games for cognitive assessment and remember to cater the solutions to the unique needs of the target population.

In conclusion, our thematic analysis contributes to the acceptance research on VR-based cognitive assessment games because it compares the feedback from the younger and older groups in primary settings. The discussion on the implications of the findings for the stakeholders provides unique perspectives on translating the findings to the real world. The limitation of the study is the lack of follow-up on game use and adaptation. We believe that a longitudinal monitoring of user attitudes and perceptions would provide a stronger understanding of acceptance and adoption of VR games for cognitive assessment. As a future direction, researchers are advised to monitor game use in the long term, preferably 6 months. In addition, we tested these games in only 2 age groups (18-28 and >60 years) and,

therefore, recommend also testing and piloting these games in middle-aged groups (30-50 years). These results would provide more clarity on the overall effectiveness of the VR games to capture age-related cognitive decline. Finally, we piloted these games in healthy groups, so it is strongly suggested to obtain feedback from people with mild cognitive impairment, who are at a greater risk of developing dementia.

Finally, we believe that VR is an immensely novel and exciting tool and it is easy to be swayed by the thrill of technology. Therefore, it is important to remind ourselves to use it in a responsible manner such that human safety and benefits are honored over purely commercial and monetary interests.

Acknowledgments

The authors would like to thank Dr Ratnavalli Ellajosyula, senior consultant neurologist; Dr Jwala Narayanan, consultant neuropsychologist; and Sandhya Sivakumar, intern at Annasawmy Mudaliar General Hospital, Bangalore, for their extensive support in the conduct of the study for older people at the hospital. The authors would also like to acknowledge the infrastructure and facilities at Annasawmy Mudaliar General Hospital, Bangalore, and the Cognitive Neuroscience Lab, Birla Institute of Technology and Science (BITS) Pilani K. K. Birla Campus, Goa, India. The authors acknowledge funding support under strategic research projects from BITS BioCyTiH Foundation (a Section-8 not-for-profit company) hosted by BITS Pilani, supported under the National Mission on Interdisciplinary Cyber Physical Systems, Department of Science and Technology, Government of India.

Authors' Contributions

YB conceptualized the study, collated interview data, conducted the thematic analysis, and wrote the manuscript. VB supervised the study and reviewed the manuscript for intellectual content. Both authors approve of the manuscript.

Conflicts of Interest

None declared.

References

1. Rabbitt PM, Banerji N, Szymanski A. Space fortress as an IQ test? Predictions of learning and of practised performance in a complex interactive video-game. *Acta Psychologica* 1989 Aug;71(1-3):243-257. [doi: [10.1016/0001-6918\(89\)90011-5](https://doi.org/10.1016/0001-6918(89)90011-5)]
2. Quiroga M, Herranz M, Gómez-Abad M, Kebir M, Ruiz J, Colom R. Video-games: do they require general intelligence? *Comput Educ* 2009 Sep;53(2):414-418. [doi: [10.1016/j.compedu.2009.02.017](https://doi.org/10.1016/j.compedu.2009.02.017)]
3. Quiroga M, Román FJ, De La Fuente J, Privado J, Colom R. The measurement of intelligence in the XXI century using video games. *Span J Psychol* 2016 Dec 05;19:E89. [doi: [10.1017/sjp.2016.84](https://doi.org/10.1017/sjp.2016.84)] [Medline: [27917731](https://pubmed.ncbi.nlm.nih.gov/27917731/)]
4. Baniqued PL, Lee H, Voss MW, Basak C, Cosman JD, Desouza S, et al. Selling points: what cognitive abilities are tapped by casual video games? *Acta Psychol (Amst)* 2013 Jan;142(1):74-86 [FREE Full text] [doi: [10.1016/j.actpsy.2012.11.009](https://doi.org/10.1016/j.actpsy.2012.11.009)] [Medline: [23246789](https://pubmed.ncbi.nlm.nih.gov/23246789/)]
5. Shute VJ, Ventura M, Ke F. The power of play: the effects of portal 2 and Lumosity on cognitive and noncognitive skills. *Comput Educ* 2015 Jan;80:58-67. [doi: [10.1016/j.compedu.2014.08.013](https://doi.org/10.1016/j.compedu.2014.08.013)]
6. Lim J, Furnham A. Can commercial games function as intelligence tests? A pilot study. *Comput Game J* 2018 Feb 10;7(1):27-37. [doi: [10.1007/s40869-018-0053-z](https://doi.org/10.1007/s40869-018-0053-z)]
7. Asher S, Priefer R. Alzheimer's disease failed clinical trials. *Life Sci* 2022 Oct 01;306:120861. [doi: [10.1016/j.lfs.2022.120861](https://doi.org/10.1016/j.lfs.2022.120861)] [Medline: [35932841](https://pubmed.ncbi.nlm.nih.gov/35932841/)]
8. Sbordone RJ, Long CJ. *Ecological Validity of Neuropsychological Testing*. Boca Raton, FL: CRC Press; 1996.
9. Sbordone RJ. *Ecological validity: some critical issues for the neuropsychologist*. In: Sbordone RJ, Long C, editors. *Ecological Validity of Neuropsychological Testing*. Orlando, FL: GR Press/St. Lucie Press; 1996.
10. Sbordone RJ. *The ecological validity of neuropsychological testing*. In: Horton AM, Wedding D, Webster J, editors. *The Neuropsychology Handbook: Foundations and Assessment*. 2nd edition. Cham, Switzerland: Springer; 1997.
11. Cavedoni S, Chirico A, Pedroli E, Cipresso P, Riva G. Digital biomarkers for the early detection of mild cognitive impairment: artificial intelligence meets virtual reality. *Front Hum Neurosci* 2020 Jul 24;14:245 [FREE Full text] [doi: [10.3389/fnhum.2020.00245](https://doi.org/10.3389/fnhum.2020.00245)] [Medline: [32848660](https://pubmed.ncbi.nlm.nih.gov/32848660/)]
12. Brunner IC, Skouen JS, Hofstad H, Aßmus J, Becker F, Sanders A, et al. Virtual reality training for upper extremity in subacute stroke (VIRTUES): a multicenter RCT. *Neurology* 2017 Dec 12;89(24):2413-2421. [doi: [10.1212/WNL.0000000000004744](https://doi.org/10.1212/WNL.0000000000004744)] [Medline: [29142090](https://pubmed.ncbi.nlm.nih.gov/29142090/)]

13. Buxbaum LJ, Palermo MA, Mastrogiovanni D, Read MS, Rosenberg-Pitonyak E, Rizzo AA, et al. Assessment of spatial attention and neglect with a virtual wheelchair navigation task. *J Clin Exp Neuropsychol* 2008 Aug 14;30(6):650-660. [doi: [10.1080/13803390701625821](https://doi.org/10.1080/13803390701625821)] [Medline: [18608643](https://pubmed.ncbi.nlm.nih.gov/18608643/)]
14. Maier M, Ballester BR, Leiva Bañuelos NL, Duarte Oller E, Verschure PF. Adaptive conjunctive cognitive training (ACCT) in virtual reality for chronic stroke patients: a randomized controlled pilot trial. *J Neuroeng Rehabil* 2020 Mar 06;17(1):42 [FREE Full text] [doi: [10.1186/s12984-020-0652-3](https://doi.org/10.1186/s12984-020-0652-3)] [Medline: [32143674](https://pubmed.ncbi.nlm.nih.gov/32143674/)]
15. Nir-Hadad SY, Weiss PL, Waizman A, Schwartz N, Kizony R. A virtual shopping task for the assessment of executive functions: validity for people with stroke. *Neuropsychol Rehabil* 2017 Jul 11;27(5):808-833. [doi: [10.1080/09602011.2015.1109523](https://doi.org/10.1080/09602011.2015.1109523)] [Medline: [26558414](https://pubmed.ncbi.nlm.nih.gov/26558414/)]
16. Cox DJ, Davis MJ, Singh H, Barbour B, Nidiffer FD, Trudel T, et al. Driving rehabilitation for military personnel recovering from traumatic brain injury using virtual reality driving simulation: a feasibility study. *Mil Med* 2010 Jun;175(6):411-416. [doi: [10.7205/milmed-d-09-00081](https://doi.org/10.7205/milmed-d-09-00081)] [Medline: [20572473](https://pubmed.ncbi.nlm.nih.gov/20572473/)]
17. Jacoby M, Averbuch S, Sacher Y, Katz N, Weiss PL, Kizony R. Effectiveness of executive functions training within a virtual supermarket for adults with traumatic brain injury: a pilot study. *IEEE Trans Neural Syst Rehabil Eng* 2013 Mar;21(2):182-190. [doi: [10.1109/TNSRE.2012.2235184](https://doi.org/10.1109/TNSRE.2012.2235184)] [Medline: [23292820](https://pubmed.ncbi.nlm.nih.gov/23292820/)]
18. Jin R, Pillozzi AR, Huang X. Current cognition tests, potential virtual reality applications, and serious games in cognitive assessment and non-pharmacological therapy for neurocognitive disorders. *J Clin Med* 2020 Oct 13;9(10):3287 [FREE Full text] [doi: [10.3390/jcm9103287](https://doi.org/10.3390/jcm9103287)] [Medline: [33066242](https://pubmed.ncbi.nlm.nih.gov/33066242/)]
19. Burgess PW, Alderman N, Forbes C, Costello A, Coates LM, Dawson DR, et al. The case for the development and use of "ecologically valid" measures of executive function in experimental and clinical neuropsychology. *J Int Neuropsychol Soc* 2006 Mar 22;12(2):194-209 [FREE Full text] [doi: [10.1017/S1355617706060310](https://doi.org/10.1017/S1355617706060310)] [Medline: [16573854](https://pubmed.ncbi.nlm.nih.gov/16573854/)]
20. Parsons TD. Virtual reality for enhanced ecological validity and experimental control in the clinical, affective and social neurosciences. *Front Hum Neurosci* 2015 Dec 11;9:660 [FREE Full text] [doi: [10.3389/fnhum.2015.00660](https://doi.org/10.3389/fnhum.2015.00660)] [Medline: [26696869](https://pubmed.ncbi.nlm.nih.gov/26696869/)]
21. Rizzo A, Buckwalter JG, van der Zaag C, Neumann U, Thiebaut M, Chua C, et al. Virtual environment applications in clinical neuropsychology. In: *Proceedings of the 2000 Conference on IEEE Virtual Reality*. 2000 Presented at: VR '00; March 18-20, 2000; New Brunswick, NJ p. 63-70 URL: <https://ieeexplore.ieee.org/document/840364> [doi: [10.1109/vr.2000.840364](https://doi.org/10.1109/vr.2000.840364)]
22. Tarnanas IA, Schlee W, Tsolaki M, Müri RM, Mosimann U, Nef T. Ecological validity of virtual reality daily living activities screening for early dementia: longitudinal study. *JMIR Serious Games* 2013 Aug 06;1(1):e1 [FREE Full text] [doi: [10.2196/games.2778](https://doi.org/10.2196/games.2778)] [Medline: [25658491](https://pubmed.ncbi.nlm.nih.gov/25658491/)]
23. Cushman LA, Stein KK, Duffy CJ. Detecting navigational deficits in cognitive aging and Alzheimer disease using virtual reality. *Neurology* 2008 Sep 16;71(12):888-895 [FREE Full text] [doi: [10.1212/01.wnl.0000326262.67613.fe](https://doi.org/10.1212/01.wnl.0000326262.67613.fe)] [Medline: [18794491](https://pubmed.ncbi.nlm.nih.gov/18794491/)]
24. Byagowi A, Moussavi Z. Design of a virtual reality navigational (VRN) experiment for assessment of egocentric spatial cognition. *Annu Int Conf IEEE Eng Med Biol Soc* 2012;2012:4812-4815. [doi: [10.1109/EMBC.2012.6347070](https://doi.org/10.1109/EMBC.2012.6347070)] [Medline: [23367004](https://pubmed.ncbi.nlm.nih.gov/23367004/)]
25. Kizony R, Zeilig G, Krasovsky T, Bondi M, Weiss P, Kodesh E, et al. Using virtual reality simulation to study navigation in a complex environment as a functional-cognitive task; a pilot study. *J Vestib Res* 2017;27(1):39-47. [doi: [10.3233/VES-170605](https://doi.org/10.3233/VES-170605)] [Medline: [28387691](https://pubmed.ncbi.nlm.nih.gov/28387691/)]
26. Lim JE, Wong WT, Teh TA, Lim SH, Allen JC, Quah JH, et al. A fully-immersive and automated virtual reality system to assess the six domains of cognition: protocol for a feasibility study. *Front Aging Neurosci* 2020 Jan 7;12:604670 [FREE Full text] [doi: [10.3389/fnagi.2020.604670](https://doi.org/10.3389/fnagi.2020.604670)] [Medline: [33488382](https://pubmed.ncbi.nlm.nih.gov/33488382/)]
27. Pallavicini F, Pepe A, Minissi ME. Taking neuropsychological test to the next level: commercial virtual reality video games for the assessment of executive functions. In: *Proceedings of the 13th International Conference, UAHCI 2019, Held as Part of the 21st HCI International Conference on Universal Access in Human-Computer Interaction: Multimodality and Assistive Environments*. 2019 Presented at: HCII '19; July 26-31, 2019; Orlando, FL p. 2019 URL: https://link.springer.com/chapter/10.1007/978-3-030-23563-5_12 [doi: [10.1007/978-3-030-23563-5_12](https://doi.org/10.1007/978-3-030-23563-5_12)]
28. Kizony R, Josman N, Katz N, Rand D, Patrice L. Virtual reality and the rehabilitation of executive functions: an annotated bibliography. *Israel J Occup Ther* 2021;2(2008):E47-E61 [FREE Full text]
29. Optale G, Urgesi C, Busato V, Marin S, Piron L, Priftis K, et al. Controlling memory impairment in elderly adults using virtual reality memory training: a randomized controlled pilot study. *Neurorehabil Neural Repair* 2010 May 24;24(4):348-357. [doi: [10.1177/1545968309353328](https://doi.org/10.1177/1545968309353328)] [Medline: [19934445](https://pubmed.ncbi.nlm.nih.gov/19934445/)]
30. Brooks BM, Rose FD. The use of virtual reality in memory rehabilitation: current findings and future directions. *NeuroRehabilitation* 2003 Jun 27;18(2):147-157. [doi: [10.3233/NRE-2003-18207](https://doi.org/10.3233/NRE-2003-18207)]
31. Matheis RJ, Schultheis MT, Tiersky LA, DeLuca J, Millis SR, Rizzo AA. Is learning and memory different in a virtual environment? *Clin Neuropsychol* 2007 Jan 31;21(1):146-161. [doi: [10.1080/13854040601100668](https://doi.org/10.1080/13854040601100668)] [Medline: [17366282](https://pubmed.ncbi.nlm.nih.gov/17366282/)]

32. Mrkac-Sposta S, Di Santo SG, Franchini F, Arlati S, Zangiacomì A, Greci L, et al. Effects of combined physical and cognitive virtual reality-based training on cognitive impairment and oxidative stress in MCI patients: a pilot study. *Front Aging Neurosci* 2018 Oct 1;10:282 [FREE Full text] [doi: [10.3389/fnagi.2018.00282](https://doi.org/10.3389/fnagi.2018.00282)] [Medline: [30327596](https://pubmed.ncbi.nlm.nih.gov/30327596/)]
33. Giachero A, Calati M, Pia L, La Vista L, Molo M, Rugiero C, et al. Conversational therapy through semi-immersive virtual reality environments for language recovery and psychological well-being in post stroke aphasia. *Behav Neurol* 2020 Aug 06;2020:2846046-2846015 [FREE Full text] [doi: [10.1155/2020/2846046](https://doi.org/10.1155/2020/2846046)] [Medline: [32831969](https://pubmed.ncbi.nlm.nih.gov/32831969/)]
34. Park JS, Jung YJ, Lee G. Virtual reality-based cognitive-motor rehabilitation in older adults with mild cognitive impairment: a randomized controlled study on motivation and cognitive function. *Healthcare (Basel)* 2020 Sep 11;8(3):335 [FREE Full text] [doi: [10.3390/healthcare8030335](https://doi.org/10.3390/healthcare8030335)] [Medline: [32932997](https://pubmed.ncbi.nlm.nih.gov/32932997/)]
35. Weiner EJ, Sanchez DR. Cognitive ability in virtual reality: validity evidence for VR game - based assessments. *Int J Sel Assess* 2020 Jun 14;28(3):215-235. [doi: [10.1111/ijssa.12295](https://doi.org/10.1111/ijssa.12295)]
36. Negu A, Matu S, Sava FA, David DO. Virtual reality measures in neuropsychological assessment: a meta-analytic review. *Clin Neuropsychol* 2016 Feb 29;30(2):165-184. [doi: [10.1080/13854046.2016.1144793](https://doi.org/10.1080/13854046.2016.1144793)] [Medline: [26923937](https://pubmed.ncbi.nlm.nih.gov/26923937/)]
37. Lin C, Ren Y, Lu A. The effectiveness of virtual reality games in improving cognition, mobility, and emotion in elderly post-stroke patients: a systematic review and meta-analysis. *Neurosurg Rev* 2023 Jul 06;46(1):167. [doi: [10.1007/s10143-023-02061-w](https://doi.org/10.1007/s10143-023-02061-w)] [Medline: [37415057](https://pubmed.ncbi.nlm.nih.gov/37415057/)]
38. Kim O, Pang Y, Kim JH. The effectiveness of virtual reality for people with mild cognitive impairment or dementia: a meta-analysis. *BMC Psychiatry* 2019 Jul 12;19(1):219 [FREE Full text] [doi: [10.1186/s12888-019-2180-x](https://doi.org/10.1186/s12888-019-2180-x)] [Medline: [31299921](https://pubmed.ncbi.nlm.nih.gov/31299921/)]
39. Hedman J, Gimpel G. The adoption of hyped technologies: a qualitative study. *Inf Technol Manag* 2010 Oct 6;11(4):161-175. [doi: [10.1007/S10799-010-0075-0](https://doi.org/10.1007/S10799-010-0075-0)]
40. Gilly MC, Sheth JN, Newman BI, Gross BL. *Consumption Values and Market Choices: Theory and Applications*. Nashville, TN: South-Western Publication; Nov 1992.
41. Sheth JN, Newman BI, Gross BL. Why we buy what we buy: a theory of consumption values. *J Bus Res* 1991 Mar;22(2):159-170. [doi: [10.1016/0148-2963\(91\)90050-8](https://doi.org/10.1016/0148-2963(91)90050-8)]
42. Horan WP, Depp CA, Hurst S, Linthicum J, Vargas G, Klein H, et al. Qualitative analysis of the content validity of the virtual reality functional capacity assessment tool (VRFCAT) in schizophrenia: a multi-stakeholder perspective. *Schizophr Bull Open* 2023 Jan;4(1):sgad012 [FREE Full text] [doi: [10.1093/schizbullopen/sgad012](https://doi.org/10.1093/schizbullopen/sgad012)] [Medline: [38026054](https://pubmed.ncbi.nlm.nih.gov/38026054/)]
43. Catania V, Rundo F, Panerai S, Ferri R. Virtual reality for the rehabilitation of acquired cognitive disorders: a narrative review. *Bioengineering (Basel)* 2023 Dec 28;11(1):35 [FREE Full text] [doi: [10.3390/bioengineering11010035](https://doi.org/10.3390/bioengineering11010035)] [Medline: [38247912](https://pubmed.ncbi.nlm.nih.gov/38247912/)]
44. Kari T, Kosa M. Acceptance and use of virtual reality games: an extension of HMSAM. *Virtual Real* 2023 Jan 31;27(3):1-21 [FREE Full text] [doi: [10.1007/s10055-023-00749-4](https://doi.org/10.1007/s10055-023-00749-4)] [Medline: [36742344](https://pubmed.ncbi.nlm.nih.gov/36742344/)]
45. Faric N, Potts HW, Hon A, Smith L, Newby K, Steptoe A, et al. What players of virtual reality exercise games want: thematic analysis of web-based reviews. *J Med Internet Res* 2019 Sep 16;21(9):e13833 [FREE Full text] [doi: [10.2196/13833](https://doi.org/10.2196/13833)] [Medline: [31538951](https://pubmed.ncbi.nlm.nih.gov/31538951/)]
46. Jang Y, Park E. An adoption model for virtual reality games: the roles of presence and enjoyment. *Telemat Inform* 2019 Sep;42:101239. [doi: [10.1016/j.tele.2019.101239](https://doi.org/10.1016/j.tele.2019.101239)]
47. Tao G, Garrett B, Taverner T, Cordingley E, Sun C. Immersive virtual reality health games: a narrative review of game design. *J Neuroeng Rehabil* 2021 Feb 11;18(1):31 [FREE Full text] [doi: [10.1186/s12984-020-00801-3](https://doi.org/10.1186/s12984-020-00801-3)] [Medline: [33573684](https://pubmed.ncbi.nlm.nih.gov/33573684/)]
48. Ferreira-Brito F, Fialho M, Virgolino A, Neves I, Miranda AC, Sousa-Santos N, et al. Game-based interventions for neuropsychological assessment, training and rehabilitation: which game-elements to use? A systematic review. *J Biomed Inform* 2019 Oct;98:103287 [FREE Full text] [doi: [10.1016/j.jbi.2019.103287](https://doi.org/10.1016/j.jbi.2019.103287)] [Medline: [31518700](https://pubmed.ncbi.nlm.nih.gov/31518700/)]
49. Wiley K, Robinson RB, Mandryk RL. The making and evaluation of digital games used for the assessment of attention: systematic review. *JMIR Serious Games* 2021 Aug 09;9(3):e26449 [FREE Full text] [doi: [10.2196/26449](https://doi.org/10.2196/26449)] [Medline: [34383674](https://pubmed.ncbi.nlm.nih.gov/34383674/)]
50. Cherniack EP. Not just fun and games: applications of virtual reality in the identification and rehabilitation of cognitive disorders of the elderly. *Disabil Rehabil Assist Technol* 2011 Dec 15;6(4):283-289. [doi: [10.3109/17483107.2010.542570](https://doi.org/10.3109/17483107.2010.542570)] [Medline: [21158520](https://pubmed.ncbi.nlm.nih.gov/21158520/)]
51. Rizzo AA, Buckwalter JG, Neumann U, Kesselman C, Thiebaut M. Basic issues in the application of virtual reality for the assessment and rehabilitation of cognitive impairments and functional disabilities. *Cyberpsychol Behav* 1998 Jan;1(1):59-78. [doi: [10.1089/cpb.1998.1.59](https://doi.org/10.1089/cpb.1998.1.59)]
52. Cai J, Wohn DY, Mittal A, Sureshbabu D. Utilitarian and hedonic motivations for live streaming shopping. In: *Proceedings of the 2018 ACM International Conference on Interactive Experiences for TV and Online Video*. 2018 Presented at: TVX '18; June 26-28, 2018; Seoul, Republic of Korea p. 81-88 URL: <https://dl.acm.org/doi/10.1145/3210825.3210837> [doi: [10.1145/3210825.3210837](https://doi.org/10.1145/3210825.3210837)]
53. Childers TL, Carr CL, Peck J, Carson SJ. Hedonic and utilitarian motivations for online retail shopping behavior. *J Retail* 2001 Dec;77(4):511-535. [doi: [10.1016/s0022-4359\(01\)00056-2](https://doi.org/10.1016/s0022-4359(01)00056-2)]

54. Lumsden J, Edwards EA, Lawrence NS, Coyle D, Munafò MR. Gamification of cognitive assessment and cognitive training: a systematic review of applications and efficacy. *JMIR Serious Games* 2016 Jul 15;4(2):e11 [FREE Full text] [doi: [10.2196/games.5888](https://doi.org/10.2196/games.5888)] [Medline: [27421244](https://pubmed.ncbi.nlm.nih.gov/27421244/)]
55. Chuah SH, Hoffmann R, Jones MK, Williams G. Do cultures clash? Evidence from cross-national ultimatum game experiments. *J Econ Behav Organ* 2007 Sep;64(1):35-48 [FREE Full text] [doi: [10.1016/j.jebo.2006.04.006](https://doi.org/10.1016/j.jebo.2006.04.006)]
56. Lee SC, Suh YH, Kim JK, Lee KJ. A cross-national market segmentation of online game industry using SOM. *Expert Syst Appl* 2004 Nov;27(4):559-570. [doi: [10.1016/j.eswa.2004.06.001](https://doi.org/10.1016/j.eswa.2004.06.001)]
57. van der Heijden H. User acceptance of hedonic information systems. *MIS Q* 2004;28(4):695-704. [doi: [10.2307/25148660](https://doi.org/10.2307/25148660)]
58. Salthouse TA. When does age-related cognitive decline begin? *Neurobiol Aging* 2009 Apr;30(4):507-514 [FREE Full text] [doi: [10.1016/j.neurobiolaging.2008.09.023](https://doi.org/10.1016/j.neurobiolaging.2008.09.023)] [Medline: [19231028](https://pubmed.ncbi.nlm.nih.gov/19231028/)]
59. Allen JS, Bruss JE, Brown CK, Damasio H. Normal neuroanatomical variation due to age: the major lobes and a parcellation of the temporal region. *Neurobiol Aging* 2005 Oct;26(9):1245-1282. [doi: [10.1016/j.neurobiolaging.2005.05.023](https://doi.org/10.1016/j.neurobiolaging.2005.05.023)] [Medline: [16046030](https://pubmed.ncbi.nlm.nih.gov/16046030/)]
60. Fotenos AF, Snyder AZ, Girton LE, Morris JC, Buckner RL. Normative estimates of cross-sectional and longitudinal brain volume decline in aging and AD. *Neurology* 2005 Mar 22;64(6):1032-1039. [doi: [10.1212/01.wnl.0000154530.72969.11](https://doi.org/10.1212/01.wnl.0000154530.72969.11)]
61. Kruggel F. MRI-based volumetry of head compartments: normative values of healthy adults. *Neuroimage* 2006 Mar;30(1):1-11. [doi: [10.1016/j.neuroimage.2005.09.063](https://doi.org/10.1016/j.neuroimage.2005.09.063)] [Medline: [16289929](https://pubmed.ncbi.nlm.nih.gov/16289929/)]
62. Pieperhoff P, Hömke L, Schneider F, Habel U, Shah NJ, Zilles K, et al. Deformation field morphometry reveals age-related structural differences between the brains of adults up to 51 years. *J Neurosci* 2008 Jan 23;28(4):828-842 [FREE Full text] [doi: [10.1523/JNEUROSCI.3732-07.2008](https://doi.org/10.1523/JNEUROSCI.3732-07.2008)] [Medline: [18216191](https://pubmed.ncbi.nlm.nih.gov/18216191/)]
63. Sowell ER, Peterson BS, Thompson PM, Welcome SE, Henkenius AL, Toga AW. Mapping cortical change across the human life span. *Nat Neurosci* 2003 Mar 27;6(3):309-315. [doi: [10.1038/nn1008](https://doi.org/10.1038/nn1008)] [Medline: [12548289](https://pubmed.ncbi.nlm.nih.gov/12548289/)]
64. Magnotta V, Andreasen N, Schultz S, Harris G, Cizadlo T, Heckel D, et al. Quantitative in vivo measurement of gyrfication in the human brain: changes associated with aging. *Cereb Cortex* 1999 Mar;9(2):151-160. [doi: [10.1093/cercor/9.2.151](https://doi.org/10.1093/cercor/9.2.151)] [Medline: [10220227](https://pubmed.ncbi.nlm.nih.gov/10220227/)]
65. Salat DH, Buckner RL, Snyder AZ, Greve DN, Desikan RS, Busa E, et al. Thinning of the cerebral cortex in aging. *Cereb Cortex* 2004 Jul 28;14(7):721-730. [doi: [10.1093/cercor/bhh032](https://doi.org/10.1093/cercor/bhh032)] [Medline: [15054051](https://pubmed.ncbi.nlm.nih.gov/15054051/)]
66. Hsu JL, Leemans A, Bai CH, Lee C, Tsai Y, Chiu H, et al. Gender differences and age-related white matter changes of the human brain: a diffusion tensor imaging study. *Neuroimage* 2008 Jan 15;39(2):566-577. [doi: [10.1016/j.neuroimage.2007.09.017](https://doi.org/10.1016/j.neuroimage.2007.09.017)] [Medline: [17951075](https://pubmed.ncbi.nlm.nih.gov/17951075/)]
67. Sullivan EV, Pfefferbaum A. Diffusion tensor imaging and aging. *Neurosci Biobehav Rev* 2006 Jan;30(6):749-761. [doi: [10.1016/j.neubiorev.2006.06.002](https://doi.org/10.1016/j.neubiorev.2006.06.002)] [Medline: [16887187](https://pubmed.ncbi.nlm.nih.gov/16887187/)]
68. Salthouse TA. Independence of age-related influences on cognitive abilities across the life span. *Dev Psychol* 1998 Sep;34(5):851-864. [doi: [10.1037//0012-1649.34.5.851](https://doi.org/10.1037//0012-1649.34.5.851)] [Medline: [9779733](https://pubmed.ncbi.nlm.nih.gov/9779733/)]
69. Salthouse TA. Relations between cognitive abilities and measures of executive functioning. *Neuropsychology* 2005 Jul;19(4):532-545. [doi: [10.1037/0894-4105.19.4.532](https://doi.org/10.1037/0894-4105.19.4.532)] [Medline: [16060828](https://pubmed.ncbi.nlm.nih.gov/16060828/)]
70. Salthouse TA, Atkinson TM, Berish DE. Executive functioning as a potential mediator of age-related cognitive decline in normal adults. *J Exp Psychol Gen* 2003 Dec;132(4):566-594. [doi: [10.1037/0096-3445.132.4.566](https://doi.org/10.1037/0096-3445.132.4.566)] [Medline: [14640849](https://pubmed.ncbi.nlm.nih.gov/14640849/)]
71. Schroeder DH, Salthouse TA. Age-related effects on cognition between 20 and 50 years of age. *Pers Individ Dif* 2004 Jan;36(2):393-404. [doi: [10.1016/S0191-8869\(03\)00104-1](https://doi.org/10.1016/S0191-8869(03)00104-1)]
72. Jones HE, Conrad HS. The growth and decline of intelligence: a study of a homogeneous group between the ages of ten and sixty. *Genet Psychol Monogr* 1933;13:223-298 [FREE Full text]
73. Kim HK, Park J, Choi Y, Choe M. Virtual reality sickness questionnaire (VRSQ): motion sickness measurement index in a virtual reality environment. *Appl Ergon* 2018 May;69:66-73. [doi: [10.1016/j.apergo.2017.12.016](https://doi.org/10.1016/j.apergo.2017.12.016)] [Medline: [29477332](https://pubmed.ncbi.nlm.nih.gov/29477332/)]
74. Witmer BG, Jerome CJ, Singer MJ. The factor structure of the presence questionnaire. *Presence* 2005;14(3):298-312. [doi: [10.1162/105474698565686](https://doi.org/10.1162/105474698565686)]
75. Brooke JB. SUS: A 'Quick and Dirty' Usability Scale. Boca Raton, FL: CRC Press; 1996.
76. Rebenitsch L, Owen C. Estimating cybersickness from virtual reality applications. *Virtual Real* 2020 May 28;25(1):165-174. [doi: [10.1007/S10055-020-00446-6](https://doi.org/10.1007/S10055-020-00446-6)]
77. Chen Y, Wu Z. A review on ergonomics evaluations of virtual reality. *Work* 2023;74(3):831-841. [doi: [10.3233/WOR-205232](https://doi.org/10.3233/WOR-205232)] [Medline: [36442175](https://pubmed.ncbi.nlm.nih.gov/36442175/)]
78. Zhuang J, Liu Y, Jia Y, Huang Y. User discomfort evaluation research on the weight and wearing mode of head-wearable device. In: *Proceedings of the AHFE 2018 International Conferences on Human Factors and Wearable Technologies, and Human Factors in Game Design and Virtual Environments*. 2018 Presented at: AHFE '18; July 21-25, 2018; Orlando, FL p. 98-110 URL: https://link.springer.com/chapter/10.1007/978-3-319-94619-1_10 [doi: [10.1007/978-3-319-94619-1_10](https://doi.org/10.1007/978-3-319-94619-1_10)]
79. Kim E, Shin G. User discomfort while using a virtual reality headset as a personal viewing system for text-intensive office tasks. *Ergonomics* 2021 Jul 08;64(7):891-899. [doi: [10.1080/00140139.2020.1869320](https://doi.org/10.1080/00140139.2020.1869320)] [Medline: [33357004](https://pubmed.ncbi.nlm.nih.gov/33357004/)]
80. LeClair B, O'Connor PJ, Podrucky S, Lievers WB. Measuring the mass and center of gravity of helmet systems for underground workers. *Int J Ind Ergon* 2018 Mar;64:23-30. [doi: [10.1016/j.ergon.2017.10.001](https://doi.org/10.1016/j.ergon.2017.10.001)]

81. Heller B. VR is failing the very people it could benefit most. The Information. 2022. URL: <https://pacscenter.stanford.edu/wp-content/uploads/2022/08/VR-Is-Failing-the-Very-People-It-Could-Benefit-Most-%E2%80%94-The-Information.pdf> [accessed 2024-04-29]
82. Palombo R, Weber S, Wyszynski M, Niehaves B. Glove versus controller: the effect of VR gloves and controllers on presence, embodiment, and cognitive absorption. *Front Virtual Real* 2024 Mar 26;5:1-11. [doi: [10.3389/frvir.2024.1337959](https://doi.org/10.3389/frvir.2024.1337959)]
83. Popovici DM, Marhan AM. Virtual reality-based environments for learning and training. In: *Product Engineering: Tools and Methods Based on Virtual Reality*. Cham, Switzerland: Springer; 2008:123-142.
84. Checa D, Bustillo A. A review of immersive virtual reality serious games to enhance learning and training. *Multimed Tools Appl* 2019 Dec 05;79(9-10):5501-5527. [doi: [10.1007/S11042-019-08348-9](https://doi.org/10.1007/S11042-019-08348-9)]
85. Kamińska D, Zwoliński G, Laska-Leśniewicz A. Usability testing of virtual reality applications-the pilot study. *Sensors (Basel)* 2022 Feb 10;22(4):1342 [FREE Full text] [doi: [10.3390/s22041342](https://doi.org/10.3390/s22041342)] [Medline: [35214246](https://pubmed.ncbi.nlm.nih.gov/35214246/)]
86. Gustavsson M, Kjörk EK, Erhardsson M, Alt Murphy MA. Virtual reality gaming in rehabilitation after stroke - user experiences and perceptions. *Disabil Rehabil* 2022 Nov 31;44(22):6759-6765 [FREE Full text] [doi: [10.1080/09638288.2021.1972351](https://doi.org/10.1080/09638288.2021.1972351)] [Medline: [34465269](https://pubmed.ncbi.nlm.nih.gov/34465269/)]
87. Chan YK, Tang YM, Teng L. A comparative analysis of digital health usage intentions towards the adoption of virtual reality in telerehabilitation. *Int J Med Inform* 2023 Jun;174:105042. [doi: [10.1016/j.ijmedinf.2023.105042](https://doi.org/10.1016/j.ijmedinf.2023.105042)] [Medline: [36965405](https://pubmed.ncbi.nlm.nih.gov/36965405/)]
88. Hashtroudi S, Chrosniak LD, Schwartz BL. Effects of aging on priming and skill learning. *Psychol Aging* 1991 Dec;6(4):605-615. [doi: [10.1037//0882-7974.6.4.605](https://doi.org/10.1037//0882-7974.6.4.605)] [Medline: [1777149](https://pubmed.ncbi.nlm.nih.gov/1777149/)]
89. Dennison MS, Wisti AZ, D'Zmura M. Use of physiological signals to predict cybersickness. *Displays* 2016 Sep;44:42-52. [doi: [10.1016/j.displa.2016.07.002](https://doi.org/10.1016/j.displa.2016.07.002)]
90. Dużmańska N, Strojny P, Strojny A. Can simulator sickness be avoided? A review on temporal aspects of simulator sickness. *Front Psychol* 2018 Nov 6;9:2132 [FREE Full text] [doi: [10.3389/fpsyg.2018.02132](https://doi.org/10.3389/fpsyg.2018.02132)] [Medline: [30459688](https://pubmed.ncbi.nlm.nih.gov/30459688/)]
91. Stanney K, Lawson BD, Rokers B, Dennison M, Fidopiastis C, Stoffregen T, et al. Identifying causes of and solutions for cybersickness in immersive technology: reformulation of a research and development agenda. *Int J Hum Comput Interact* 2020 Nov 04;36(19):1783-1803. [doi: [10.1080/10447318.2020.1828535](https://doi.org/10.1080/10447318.2020.1828535)]
92. Yildirim C. Don't make me sick: investigating the incidence of cybersickness in commercial virtual reality headsets. *Virtual Real* 2019 Aug 20;24(2):231-239. [doi: [10.1007/S10055-019-00401-0](https://doi.org/10.1007/S10055-019-00401-0)]
93. Davis S, Nesbitt KV, Nalivaiko E. A systematic review of cybersickness. In: *Proceedings of the 2014 Conference on Interactive Entertainment*. 2014 Presented at: IE '14; December 2-3, 2014; Newcastle, Australia p. 1-9 URL: <https://dl.acm.org/doi/10.1145/2677758.2677780> [doi: [10.1145/2677758.2677780](https://doi.org/10.1145/2677758.2677780)]
94. Rebenitsch L, Owen CB. Review on cybersickness in applications and visual displays. *Virtual Real* 2016 Apr 26;20(2):101-125. [doi: [10.1007/S10055-016-0285-9](https://doi.org/10.1007/S10055-016-0285-9)]
95. Chang E, Kim HT, Yoo B. Virtual reality sickness: a review of causes and measurements. *Int J Hum Comput Interact* 2020 Jul 02;36(17):1658-1682. [doi: [10.1080/10447318.2020.1778351](https://doi.org/10.1080/10447318.2020.1778351)]
96. Descheneaux CR, Reinerman-Jones L, Moss JD, Krum DM, Hudson IL. Negative effects associated with HMDs in augmented and virtual reality. In: *Proceedings of the 12th International Conference Held as Part of the 22nd HCI International Conference on Virtual, Augmented and Mixed Reality, Design and Interaction*. 2020 Presented at: VAMR '20; July 19-24, 2020; Copenhagen, Denmark p. 410-428 URL: https://dl.acm.org/doi/10.1007/978-3-030-49695-1_27 [doi: [10.1007/978-3-030-49695-1_27](https://doi.org/10.1007/978-3-030-49695-1_27)]
97. Sugita N, Yamaga T, Yoshizawa M. Visual fatigue induced by accommodation convergence mismatch while viewing three-dimensional television. In: *Proceedings of the 3rd Global Conference on Consumer Electronics*. 2014 Presented at: GCCE '14; October 7-10, 2014; Tokyo, Japan p. 250-251 URL: <https://ieeexplore.ieee.org/document/7031210> [doi: [10.1109/gcce.2014.7031210](https://doi.org/10.1109/gcce.2014.7031210)]
98. Grassini S, Laumann K. Immersive visual technologies and human health. In: *Proceedings of the 32nd European Conference on Cognitive Ergonomics*. 2021 Presented at: ECCE '21; April 26-29, 2021; Siena, Italy p. 1-6 URL: <https://dl.acm.org/doi/10.1145/3452853.3452856> [doi: [10.1145/3452853.3452856](https://doi.org/10.1145/3452853.3452856)]
99. Souchet AD, Lourdeaux D, Pagani A, Rebenitsch L. A narrative review of immersive virtual reality's ergonomics and risks at the workplace: cybersickness, visual fatigue, muscular fatigue, acute stress, and mental overload. *Virtual Real* 2022 Jul 16;27(1):19-50. [doi: [10.1007/S10055-022-00672-0](https://doi.org/10.1007/S10055-022-00672-0)]
100. Kim JY, Kim SH, So GJ. The modeling of color fatigue in 3-dimensional stereoscopic video. *Int J Comput Eng Res* 2016 Jun;8(3):229-234. [doi: [10.7763/ijcte.2016.v8.1049](https://doi.org/10.7763/ijcte.2016.v8.1049)]
101. Kweon SH, Kweon H, Kim SJ, Li X, Liu X, Kweon H. A brain wave research on VR (virtual reality) usage: comparison between VR and 2D video in EEG measurement. In: *Proceedings of the 2017 International Conference on Human Factors and Systems Interaction*. 2017 Presented at: AHFE '17; July 17-21, 2017; Los Angeles, CA p. 194-203 URL: https://link.springer.com/chapter/10.1007/978-3-319-60366-7_19 [doi: [10.1007/978-3-319-60366-7_19](https://doi.org/10.1007/978-3-319-60366-7_19)]
102. Hvass JS, Larsen O, Vendelbo KB, Nilsson NC, Nordahl R, Serafin S. Visual realism and presence in a virtual reality game. In: *Proceedings of the 2017 3DTV Conference on the True Vision - Capture, Transmission and Display of 3D Video*. 2017

- Presented at: 3DTV-CON '17; June 7-9, 2017; Copenhagen, Denmark p. 1-4 URL: <https://ieeexplore.ieee.org/abstract/document/8280421> [doi: [10.1109/3dtv.2017.8280421](https://doi.org/10.1109/3dtv.2017.8280421)]
103. Reer F, Wehden LO, Janzik R, Tang WY, Quandt T. Virtual reality technology and game enjoyment: the contributions of natural mapping and need satisfaction. *Comput Human Behav* 2022 Jul;132:107242. [doi: [10.1016/j.chb.2022.107242](https://doi.org/10.1016/j.chb.2022.107242)]
 104. Jung S, Lindeman RW. Perspective: does realism improve presence in VR? Suggesting a model and metric for VR experience evaluation. *Front Virtual Real* 2021 Jul 15;2:1-7. [doi: [10.3389/frvir.2021.693327](https://doi.org/10.3389/frvir.2021.693327)]
 105. Davis FD, Bagozzi RP, Warshaw PR. User acceptance of computer technology: a comparison of two theoretical models. *Manag Sci* 1989 Aug;35(8):982-1003. [doi: [10.1287/mnsc.35.8.982](https://doi.org/10.1287/mnsc.35.8.982)]
 106. Liao S, Shao YP, Wang H, Chen AH. The adoption of virtual banking: an empirical study. *Int J Inf Manage* 1999 Feb;19(1):63-74. [doi: [10.1016/s0268-4012\(98\)00047-4](https://doi.org/10.1016/s0268-4012(98)00047-4)]
 107. Bertrand M, Bouchard S. Applying the technology acceptance model to VR with people who are favorable to its use. *J Cyber Ther Rehabil* 2008;1(2):200 [FREE Full text]
 108. Lin CP, Bhattacharjee A. Extending technology usage models to interactive hedonic technologies: a theoretical model and empirical test. *Inf Syst J* 2010 Feb 08;20(2):163-181. [doi: [10.1111/j.1365-2575.2007.00265.x](https://doi.org/10.1111/j.1365-2575.2007.00265.x)]
 109. Shin DD, Shin YJ. Why do people play social network games? *Comput Human Behav* 2011 Mar;27(2):852-861. [doi: [10.1016/j.chb.2010.11.010](https://doi.org/10.1016/j.chb.2010.11.010)]
 110. Nah FF, Eschenbrenner B, DeWester D. Enhancing brand equity through flow and telepresence: a comparison of 2D and 3D virtual worlds. *MIS Q* 2011;35(3):731. [doi: [10.2307/23042806](https://doi.org/10.2307/23042806)]
 111. Wu J, Lu X. Effects of extrinsic and intrinsic motivators on using utilitarian, hedonic, and dual-purposed information systems: a meta-analysis. *J Assoc Inf Syst* 2013 Mar;14(3):153-191. [doi: [10.17705/1jais.00325](https://doi.org/10.17705/1jais.00325)]
 112. Miskowiak KW, Jespersen AE, Kessing LV, Aggestrup AS, Glenthøj LB, Nordentoft M, et al. Cognition assessment in virtual reality: validity and feasibility of a novel virtual reality test for real-life cognitive functions in mood disorders and psychosis spectrum disorders. *J Psychiatr Res* 2021 Dec 12;145:182-189 [FREE Full text] [doi: [10.1016/j.jpsychires.2021.12.002](https://doi.org/10.1016/j.jpsychires.2021.12.002)] [Medline: [34923359](https://pubmed.ncbi.nlm.nih.gov/34923359/)]
 113. Chaytor N, Schmitter-Edgecombe M, Burr R. Improving the ecological validity of executive functioning assessment. *Arch Clin Neuropsychol* 2006 Apr;21(3):217-227. [doi: [10.1016/j.acn.2005.12.002](https://doi.org/10.1016/j.acn.2005.12.002)] [Medline: [16554143](https://pubmed.ncbi.nlm.nih.gov/16554143/)]
 114. Long CJ. Neuropsychological tests: a look at our past and the impact that ecological issues may have on our future. In: Sbordone RJ, Long CJ, editors. *Ecological Validity of Neuropsychological Testing*. Boca Raton, FL: Gr Press/St Lucie Press; 1996:1-14.
 115. Verschuere S, Buffel C, Vander Stichele G. Developing theory-driven, evidence-based serious games for health: framework based on research community insights. *JMIR Serious Games* 2019 May 02;7(2):e11565 [FREE Full text] [doi: [10.2196/11565](https://doi.org/10.2196/11565)] [Medline: [31045496](https://pubmed.ncbi.nlm.nih.gov/31045496/)]
 116. Loerzel VW, Clochesy JM, Geddie PI. Using a community advisory board to develop a serious game for older adults undergoing treatment for cancer. *Appl Nurs Res* 2018 Feb;39:207-210 [FREE Full text] [doi: [10.1016/j.apnr.2017.11.030](https://doi.org/10.1016/j.apnr.2017.11.030)] [Medline: [29422160](https://pubmed.ncbi.nlm.nih.gov/29422160/)]
 117. Agarwal R, Karahanna E. Time flies when you're having fun: cognitive absorption and beliefs about information technology usage. *MIS Q* 2000 Dec;24(4):665. [doi: [10.2307/3250951](https://doi.org/10.2307/3250951)]
 118. Cowley B, Charles DK, Black MM, Hickey RJ. Toward an understanding of flow in video games. *Comput Entertain* 2008 Jul;6(2):1-27. [doi: [10.1145/1371216.1371223](https://doi.org/10.1145/1371216.1371223)]
 119. Nah FF, Eschenbrenner BL, Zeng Q, Telaprolu VR, Sepehr S. Flow in gaming: literature synthesis and framework development. *Int J Inf Syst Manage* 2014;1(1/2):83. [doi: [10.1504/ijisam.2014.062288](https://doi.org/10.1504/ijisam.2014.062288)]
 120. Faiola A, Newlon CM, Pfaff MS, Smyslova OV. Correlating the effects of flow and telepresence in virtual worlds: enhancing our understanding of user behavior in game-based learning. *Comput Human Behav* 2013 May;29(3):1113-1121. [doi: [10.1016/j.chb.2012.10.003](https://doi.org/10.1016/j.chb.2012.10.003)]
 121. Tian N, Lopes P, Boulic R. A review of cybersickness in head-mounted displays: raising attention to individual susceptibility. *Virtual Real* 2022 Mar 10;26(4):1409-1441. [doi: [10.1007/s10055-022-00638-2](https://doi.org/10.1007/s10055-022-00638-2)]
 122. Angelov V, Petkov E, Shipkovenski G, Kalushkov T. Modern virtual reality headsets. In: *Proceedings of the 2020 International Congress on Human-Computer Interaction, Optimization and Robotic Applications*. 2020 Presented at: HORA '20; June 26-28, 2020; Ankara, Turkey p. 1-5 URL: <https://ieeexplore.ieee.org/document/9152604> [doi: [10.1109/hora49412.2020.9152604](https://doi.org/10.1109/hora49412.2020.9152604)]
 123. Muhanna MA. Virtual reality and the CAVE: taxonomy, interaction challenges and research directions. *J King Saud Univ Comput Inf Sci* 2015 Jul;27(3):344-361. [doi: [10.1016/j.jksuci.2014.03.023](https://doi.org/10.1016/j.jksuci.2014.03.023)]
 124. Yan Y, Chen K, Xie Y, Yiming S, Yonghong L. The effects of weight on comfort of virtual reality devices. In: *Proceedings of the 2018 International Conference on Ergonomics in Design*. 2018 Presented at: AHFE '18; July 21-25, 2018; Orlando, FL p. 239-248 URL: https://link.springer.com/chapter/10.1007/978-3-319-94706-8_27 [doi: [10.1007/978-3-319-94706-8_27](https://doi.org/10.1007/978-3-319-94706-8_27)]
 125. Penumudi SA, Kuppam VA, Kim JH, Hwang J. The effects of target location on musculoskeletal load, task performance, and subjective discomfort during virtual reality interactions. *Appl Ergon* 2020 Apr;84:103010. [doi: [10.1016/j.apergo.2019.103010](https://doi.org/10.1016/j.apergo.2019.103010)] [Medline: [31785450](https://pubmed.ncbi.nlm.nih.gov/31785450/)]

126. Dehghani M, Acikgoz F, Mashatan A, Lee SH. A holistic analysis towards understanding consumer perceptions of virtual reality devices in the post-adoption phase. *Behav Inf Technol* 2021 Jan 25;41(7):1453-1471. [doi: [10.1080/0144929x.2021.1876767](https://doi.org/10.1080/0144929x.2021.1876767)]
127. Saghafian M, Sitompul TA, Laumann K, Sundnes K, Lindell R. Application of human factors in the development process of immersive visual technologies: challenges and future improvements. *Front Psychol* 2021 Mar 1;12:634352 [[FREE Full text](#)] [doi: [10.3389/fpsyg.2021.634352](https://doi.org/10.3389/fpsyg.2021.634352)] [Medline: [33732195](https://pubmed.ncbi.nlm.nih.gov/33732195/)]
128. Szopa A, Soares MM, Karwowski W. *Handbook of Standards and Guidelines in Human Factors and Ergonomics*. Boca Raton, FL: CRC Press; 2021.
129. Rajan AV, Nassiri N, Akre V, Ravikumar R, Nabeel A, Buti M, et al. Virtual reality gaming addiction. In: *Proceedings of the 2018 Fifth HCT Information Technology Trends*. 2018 Presented at: ITT '18; November 28-29, 2018; Dubai, United Arab Emirates p. 358-363 URL: <https://ieeexplore.ieee.org/document/8649547> [doi: [10.1109/citit.2018.8649547](https://doi.org/10.1109/citit.2018.8649547)]
130. Lundin RM, Yeap YK, Menkes DB. Adverse effects of virtual and augmented reality interventions in psychiatry: systematic review. *JMIR Ment Health* 2023 May 05;10:e43240 [[FREE Full text](#)] [doi: [10.2196/43240](https://doi.org/10.2196/43240)] [Medline: [37145841](https://pubmed.ncbi.nlm.nih.gov/37145841/)]

Abbreviations

BITS: Birla Institute of Technology and Science

HMD: head-mounted display

VR: virtual reality

Edited by T Leung, K Martinez; submitted 05.04.24; peer-reviewed by D Bhatia, A Bustillo; comments to author 04.05.24; revised version received 20.05.24; accepted 28.05.24; published 28.06.24.

Please cite as:

Bhargava Y, Baths V

Experience of Youths and Older People With Virtual Reality Games for Cognitive Assessment: Inductive Thematic Analysis and Insights for Key Stakeholders

JMIR XR Spatial Comput 2024;1:e59197

URL: <https://xr.jmir.org/2024/1/e59197>

doi: [10.2196/59197](https://doi.org/10.2196/59197)

PMID:

©Yesoda Bhargava, Veeky Baths. Originally published in JMIR XR and Spatial Computing (<https://xr.jmir.org>), 28.06.2024. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR XR and Spatial Computing, is properly cited. The complete bibliographic information, a link to the original publication on <https://xr.jmir.org/>, as well as this copyright and license information must be included.

Publisher:
JMIR Publications
130 Queens Quay East.
Toronto, ON, M5A 3Y5
Phone: (+1) 416-583-2040
Email: support@jmir.org

<https://www.jmirpublications.com/>