Africa's Public Service Delivery and Performance Review
ISSN: (Online) 2310-2152, (Print) 2310-2195

The adoption of virtual reality technologies for training healthcare professionals

Authors:
Lario Malungana[1]
Bester Chimbo[1]

Affiliations:
[1]College of Science, Engineering and Technology, School of Computing, University of South Africa, Pretoria, South Africa

Corresponding author:
Lario Malungana,
emalunl1@unisa.ac.za

Dates:
Received: 01 July 2024
Accepted: 27 Oct. 2024
Published: 10 Dec. 2024

How to cite this article:
Malungana, L. & Chimbo, B., 2024, 'The adoption of virtual reality technologies for training healthcare professionals', *Africa's Public Service Delivery and Performance Review* 12(1), a867. https://doi.org/10.4102/apsdpr.v12i1.867

Background: The current digital transformation has resulted in a greater emphasis on the training of healthcare professionals. Therefore, adoption of virtual and augmented reality technologies in South African hospitals is hindered by the lack of service delivery by healthcare professionals.

Aim: The study aims to examine the applications of virtual and augmented reality in healthcare training for application, efficacy for healthcare professionals.

Setting: South African hospitals.

Methods: This study presents a systematic literature review guided by the PRISMA framework that evaluates the efficacy of virtual and augmented reality training in enhancing the abilities of healthcare professionals. A search was performed via the Scopus and Google Scholar databases, covering the period from 2019 to 2024.

Results: Initial studies suggest that the healthcare sector has a limited understanding of the concepts of virtual reality (VR) and augmented reality (AR). Furthermore, virtual and augmented reality technologies employ more sophisticated techniques than physical training for comprehension by creating a simulated environment.

Conclusion: The research article indicates that training through patient simulation is an effective method for educating healthcare professionals prior to healthcare professionals' clinical practice. Healthcare professionals are allowed to cultivate vital abilities and engage in practice sessions without the potential of inflicting harm on actual patients. The application of human practice can be achieved in either a clinical setting or a simulation laboratory.

Contribution: This study significantly contributes to the healthcare sector by examining the adoption of virtual and augmented reality.

Keywords: training; adoption; skills; virtual reality; augmented reality.

Introduction

The increasing popularity of virtual reality (VR) and augmented reality (AR) technologies can be attributed to the continuous advancements of both hardware and software. The existence of the VR and AR is referred to as two technological experiences that revolutionise the way digital technology interacts with the actual environment. Although both technologies are frequently thrown together, each has its own manner of interacting with the virtual world. As a result, VR and AR technologies have become revolutionary tools for healthcare training instruction, transforming the way we learn and significantly enhancing patient care. They have even become popular among healthcare professionals and provide them with a platform to safely experience and master clinical situations without putting patients or themselves at risk.

Proficiency in computer usage and readiness to accept these technologies are necessary skills for healthcare professionals. This study aims to investigate the adoption use of VR and AR in healthcare training, evaluating its usefulness and further identifying the necessary skills for the ability to use 3D tools like 3D MAX and Autodesk 3D for healthcare professionals. The adoption and use of virtual and augmented realities have the potential to facilitate immersive learning experiences; interactive simulations would result in better performance through effective training. Nevertheless, their adoption is reliant on computer-generated environments that emulate the patient's reality by means of interactive devices that transmit and receive information and are donned as goggles, headsets, gloves or body suits (Xi et al. 2022). It is important to note that the crucial factor for

achieving successful execution of these technologies is recognising obstacles and enablers (Habibzadeh et al. 2020), as well as devising methods to overcome the issues that hinder success. These technologies enable users to engage with a computer-generated environment, which can be a replica of the real world or a fictional world. The CAVE instrument is considered an expensive hardware necessary for training and facilitating the transformation of a physical environment into a virtual one by projecting interactive images onto walls that engage the senses and interact with both the present and future (Alarcon-Urbistondo, Perez-Aranda & Casado-Molina, 2024; Wang et al. 2023).

Virtual reality and AR technologies have the potential to be employed to train healthcare professionals in the field of healthcare (Buttussi, Chittaro & Valent 2020). This process encompasses the entire administrative procedure until the patient receives complete attention (Pires, Costa & Dias 2021). The utilisation of these technologies such as in virtual surgery can enhance the immersive nature of a simulated environment (Li et al. 2021). Conversely, VR and AR technologies can be utilised to address the critical abilities required to manage patients in the emergency department, particularly in for severe conditions. This study has realised that the utilisation of the VR in training purposes can be effective in minimising errors in surgical procedures, patient admissions, emergency response and helping resolve intricate difficulties (Alarcon-Urbistondo et al. 2024). Under typical conditions, VR can be advantageous for assisting patients during dialysis treatment. Furthermore, the use of VR glasses in healthcare environments can improve healthcare professionals' confidence when assisting patients by providing a realistic setting for training, as knowledge is gained through simulation (Alarcon-Urbistondo et al. 2024; Bhugaonkar, Bhugaonkar & Masne 2022; Kim & Choi 2021).

According to Bracq, Michinov and Jannin (2019), VR and AR technologies provide an extremely lifelike portrayal of the real world, enabling the identification of any dangers or problems that patients may encounter during their treatment. These technologies have advantageous implications for conducting research and facilitating the progress of training programmes for healthcare professionals (Noghabaei et al. 2020; Smith et al. 2020). The authenticity of simulation-based training offers an effective approach to addressing the complex challenges associated with the acquisition of physical knowledge and training. The existence of VR and AR technologies (Masood et al. 2024) generates a higher number of visuals and allows users to interact with virtual items, which can be identified in three immersion levels – non-immersive, semi-immersive and fully immersive (Masood et al. 2024).

This study aims to evaluate the latest advancements in the literature on the utilisation of VR by healthcare professionals during the past 5 years, and the implementation of VR technologies in the training of healthcare professionals. It addresses the main research question that focusses on 'How the VR and AR technologies training can be effective for healthcare professionals in understanding the required skills and training to provide high-quality work'.

This study presents a systematic literature review of VR studies. It analyses the existing research gaps in VR and AR technologies, identifying issues specific to healthcare, examining the limitations of current approaches and exploring the latest advancements that facilitate the implementation of these technologies. Specifically, this research focusses on the utilisation of VR in the healthcare field.

Research methods and design

This study comprises a selection of previous studies that have examined various facets of VR and AR technologies. The inclusion criteria for this review were as follows: (1) original research, (2) adoption of VR and AR technologies and healthcare and (3) articles published in English.

Study selection

This study distinguishes itself from previous research by examining a wide range of research articles indexed in the Scopus database from 2019 to 2024. The focus is on investigating the latest trends and advancements in VR and AR in the training of healthcare professionals. Papers were examined and assessed using specific keywords such as 'healthcare', 'Virtual Reality', 'Augmented Reality' and 'adoption'. The study emphasised that the adoption of VR or AR in training healthcare professionals should be closely examined. The authors screened approximately 99 articles, which were gathered from Scopus database and Google Scholar. However, because of the duplication on Google Scholar, the researchers identified that Scopus provides more identifiable literature in the detailed description. Upon analysis of titles and abstracts, 24 full texts were considered relevant for the study from both the databases (Google Scholar and Scopus). These articles were based on healthcare professionals' adoption of VR and AR technologies.

Data extraction

This study involved the individual screening of titles, accompanied by a comprehensive review of all full texts. Specific data collected included authors' names, publication year, country, sample size, study design and settings, utilised VR and AR technologies, healthcare applications and the categorisation or classification of the literature. All data were examined both statistically and qualitatively.

Quality assessment

The primary studies pertinent to this research were chosen based on keywords, titles and abstracts collected from the

databases. The researcher analysed the designated keywords, titles and abstracts across each platform (Ruparel et al. 2023). The researcher noted that keywords are favoured for effective and accurate searches. This study employed a systematic methodology to aggregate research on the application of VR and AR technologies in the training of healthcare professionals. This study examines the influence of VR and AR technologies on the healthcare sector, focussing on the period from 2019 to 2024. The following section will clarify the information sources, search terms and the criteria for inclusion and exclusion.

The selected articles span from 2019 to 2024, demonstrating the breadth of research on VR and AR within the healthcare sector. The study noted that the number of publications has varied over the years, exhibiting a distinct upward trend in the past 4 years. Out of 99 articles produced across four years, encompassing both local and international sources, 65 articles (54%) were published between 2019 and 2024. This trend signifies the rapid advancement of VR and AR within the healthcare sector.

The use of virtual and augmented reality in clinical healthcare

The healthcare industry is progressively adopting AR and VR technologies. Healthcare professionals can interact with their surroundings in a more immersive way, resulting in greater engagement and a better understanding of the topics at hand (Bracq et al. 2019). Because of the continuous decrease in the pricing of the technology devices (Smith et al. 2020), the technologies will likely become more accessible in the future. The integration of VR and AR technologies in education brings about substantial changes in the ways students gain knowledge and interact with their environment (Masood et al. 2024). These technologies offer new opportunities for students to interact with three-dimensional objects, explore their environment and improve their understanding of subjects. It is for the very same reasons that interactive simulations are offered for training, which allows one to explore complex subjects in a safe and engaging environment (Liaw et al. 2022). Not only that but the implementation of these technologies in healthcare environments has shown a positive effect on practical learning by actively engaging users and facilitating the acquisition of knowledge (Masood et al. 2024). Studies conducted by Anaraki et al. (2022) and Chung et al. (2022) demonstrated that healthcare professionals who employ these technologies experience heightened levels of interest and engagement. This, in turn, leads to improved efficiency among clinicians during patient surgeries. The main rationale behind this is that AR and VR provide a more genuine and practical experience, allowing healthcare professionals to actively participate in and examine patients' health using VR (Li et al. 2021). Both AR and VR are being utilised increasingly in diverse sectors, including industry and education. Previous research in these domains has demonstrated positive feedback regarding enhancements in employment outcomes (Chang et al. 2022).

Augmented reality and VR technologies have been utilised in various healthcare settings, including private hospitals. Currently, ongoing initiatives aim to integrate VR and AR technologies into public healthcare alongside other Fourth Industrial Revolution (4IR) technologies, including robotics, artificial intelligence (AI) and big data. This is seen particularly in primary healthcare facilities supervised by the South African government's Department of Health (DoH). Healthcare professionals can employ AR and VR technologies to comprehensively examine and interact with human in ways that are not possible in the physical world. This type of training can be quite beneficial for individuals who are beginners in the profession and possess competence in the specific area, as well as skills in computer usage (Bracq et al. 2019). It will, therefore, become a struggle for healthcare professionals with physical sensory impairments to comprehend intricate ideas without the use of visual assistive devices.

This study aims to evaluate the latest advancements in the literature on the utilisation of VR by healthcare professionals during the past 5 years. In addition, healthcare professionals must comprehend the necessary skills and training to deliver high-quality work; therefore, VR and AR technologies training is a must. Augmented reality and VR technologies have been used in various healthcare applications for training, physical therapy and surgery planning, particularly in private medical settings. By utilising VR, healthcare professionals can explore and interact with simulated surgery in ways that are not possible in the physical world. This training for healthcare professionals facilitates the creation of 3D models of a patient's anatomy, enabling surgeons to plan their surgeries accordingly. The evaluation will assess the extent of engagement and competence, as evidenced through ongoing studies. Instead of using the headsets for only therapy, the VR and AR technologies in the healthcare sector will adopt the use of the VR app in medication ordering through the device as a digital avatar; the therapy consultation held in a virtual office and can even head to a virtual pharmacy to order their prescription medicine.

Related work on the virtual reality and augmented reality study

The main aim of this research is to analyse the literature about the utilisation of VR and AR in the healthcare field within the last 5 years; therefore, the emphasis is placed on the most current advancements and patterns in this domain. This section summarises and presents the related works in this field, which encompass different goals and investigate distinct uses of the technologies in the context of teaching, learning and practising in the healthcare. The search for analogous works concentrated on the important elements inside the title, notably on the most comprehensive study in the field of education. Previous health studies have performed research encompassing literature reviews and surveys on the usage of VR and AR technologies in

healthcare (Adapa et al. 2020; Alarcon-Urbistondo et al. 2024; Brown et al. 2022; Buttussi et al. 2020; Han et al. 2022; Pires et al. 2021).

The integration of VR and AR into social learning environments also impacts other domains, particularly about learning theories (Sarkar et al. 2021). Patel et al. (2020), Boyles (2017) and Dilanchian, Andringa and Boot (2021) contend that there are impediments to the broad acceptance and utilisation of VR technology. These limitations are imposed within VR settings, which include situations that emphasise meditation, exploration and gaming. Further research has also investigated the progress made in VR and AR in other fields, including healthcare, where they are valuable for teaching healthcare personnel. In their study, Bhugaonkar et al. (2022) investigated the innovative integration of VR and AR in several industries, including healthcare. These studies offer valuable insights and highlight the significance of VR and AR in tackling external obstacles in the healthcare sector (Abrams et al. 2020; Azodo et al. 2020; Halbig et al. 2022).

Ethical considerations

The ethical approval to conduct this study was granted by the University of South Africa (2020/CSET/SOC/011).

Results and discussions

A systematic literature review was carried out employing this search strategy along with the established inclusion and exclusion criteria. The comprehensive search was conducted using terms employed between 2019 and 2024. However, current research on the application of VR and AR technologies in healthcare has identified 99 papers from the Scopus and Google Scholar database.

Key attributes to the inclusion of studies

The survey was conducted following South African examples as a baseline and did not exclude any countries. In recent years, there has been a limited amount of research that has mostly focussed on the feasibility of VR, adoption of VR and training. Figure 1 presents the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow diagram, which was utilised to identify and select the papers.

The database search yielded 99 articles, which were evaluated for inclusion in the comprehensive review (see Figure 1) Following the elimination of duplicates, 66 distinct search results were evaluated based on their abstracts. Articles that exclusively addressed technical concerns or failed to present empirical study results were removed. Consequently, a study by Han et al. (2022) was deemed suitable for further analysis as it examined the usage of VR and AR technologies for the training of healthcare professionals.

Conversely, a study by Singh, Vig and Kaunert (2024) was eliminated because of its emphasis on modernising healthcare applications for AR and VR in clinical practice and medical education, whereas this study concentrates on implementation. This abstract screening yielded 28 pertinent papers, which were further analysed, focussing mostly on the implementation of VR and AR in public healthcare. In the analysis, we sought ideals of ethical significance frequently referenced in the literature on VR or AR technologies. Furthermore, we sought to identify supplementary values associated with the implementation of VR and AR in the training of healthcare professionals that were absent from existing research. In addition to defining values, we examined their conceptualisations, the pertinent stakeholder group, the technical context and the approaches employed. The study yielded a collection of 24 publications documenting the efficacy of VR and AR in training healthcare professionals.

Figure 2 presents the different areas in which the studies have been conducted. It is noted that the medicine field has

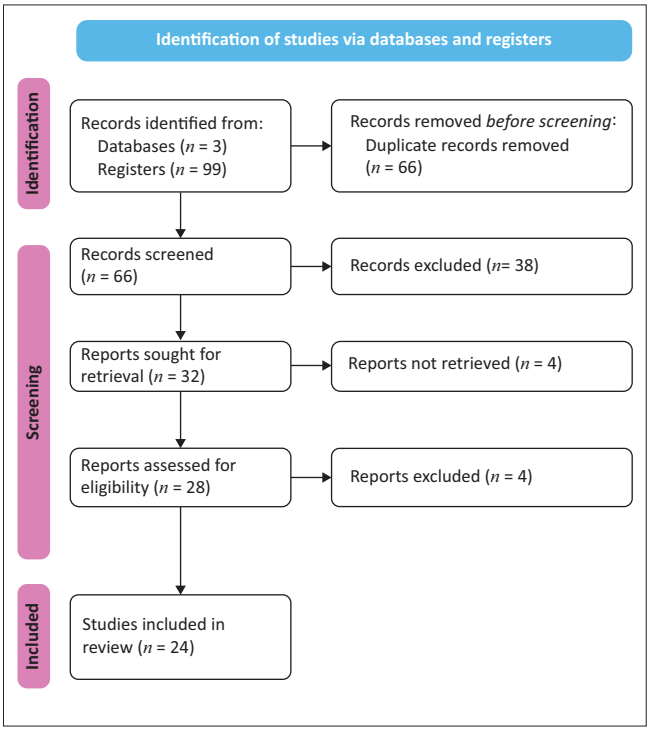

FIGURE 1: Preferred Reporting Items for Systematic reviews and Meta-Analyses flow diagram of the study selection process.

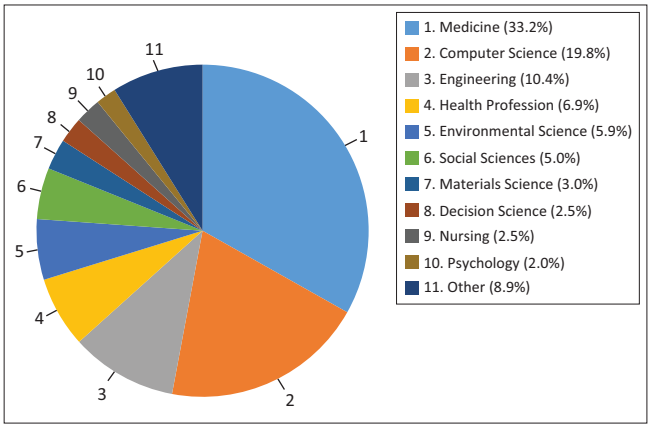

FIGURE 2: Subject areas on studies related to virtual reality and augmented reality.

the highest percentage of the studies that were conducted on VR and AR for the healthcare sector. This study is more focussed on the computing area, which is only 19.8%, reflecting that more work is required in this field other than medicine.

The investigation has included all distinct departments in order to evaluate the level of understanding of VR in a variety of research disciplines, as illustrated in Figure 2.

Figure 3 highlights a substantial improvement in publishing in this field of study from 2019 to 2024. The adoption of VR or AR technologies in healthcare was observed to have gained significant traction in 2022 but saw a slowdown in 2024 for the current publication.

Literature review revealed the United States is actively producing publications in the field of VR and AR technologies (Figure 4). Furthermore, this study demonstrated that there is a greater emphasis on examining developed countries rather than underdeveloped, as the data collection mostly targeted the most developed nations. There is ample evidence to support this claim, as numerous articles have been published instead of presenting the work at conferences.

The researchers discovered that training and obtaining knowledge helps to improve the understanding of use of

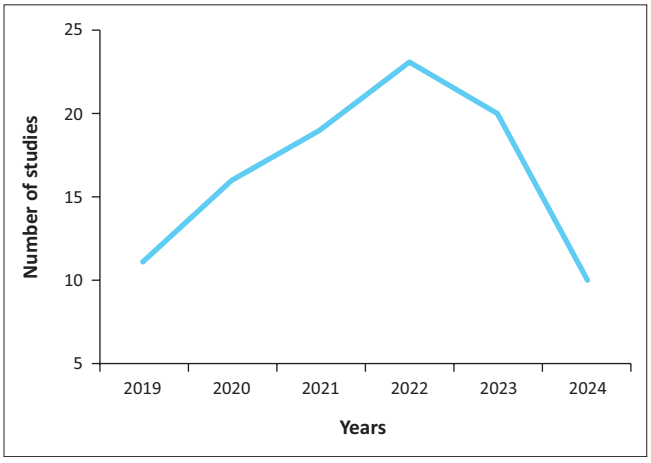

FIGURE 3: Studies conducted from 2019 to 2024 on virtual reality and augmented reality in healthcare.

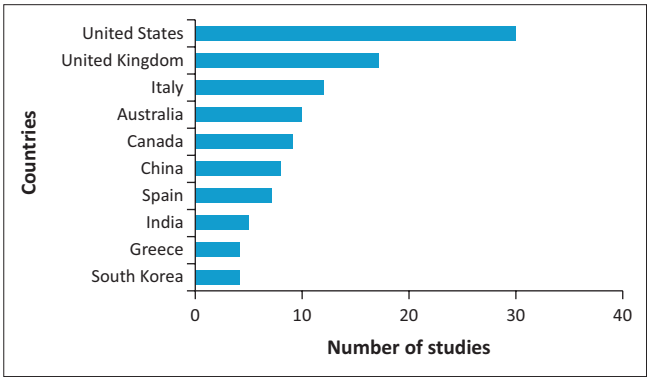

FIGURE 4: Countries where the studies were produced.

VR and AR. This study found that in healthcare, most of the publications focus on the use of VR and AR technologies, which are specific to a particular environment. However, this study focussed on the adoption of these technologies because of their readiness (Fu, Hu & Sundstedt 2022). An advantage of using VR or AR interventions is that they offer a more participatory experience, which has a good impact on the knowledge and abilities of healthcare professionals (Han et al. 2022). The study findings also showed that the outcomes of attitude and satisfaction with the adoption of VR or AR technologies are equivocal because of insufficient data on the outcomes.

This study has examined various aspects to answer the primary research question: how can the necessary skills be acquired for effective training in healthcare professions? Once there is more available data, it becomes clear and easy to adopt the use of the VR or AR technologies. This research, however, did not include any other patient-related outcome, but the focus was on addressing the training of health care professions in VR and AR technologies. Only one research study evaluated the expenses related to the maintenance of the technologies (Baashar et al. 2023). In general, the advancement of AR and VR technologies has led to increased portability of its computing devices, yet the intuition of human-computer interaction suffered a slight setback, with artificial approaches (e.g., scanner, mouse, and keyboard) outweighing natural approaches (e.g., motion trackers) (Duval et al. 2022; Quqandi et al. 2023).

In general, the studies were deemed to have an unclear risk of bias because of insufficient information. However, there were some cases where there was a potential for significant risk of attrition, reporting and other biases. The quality of evidence varies from low to moderate for knowledge, skills, attitude and satisfaction outcomes because of the presence of unclear and high risks of bias and inconsistency. This includes heterogeneity in study results, as well as variations in the types of participants, interventions and outcome measurement instruments. The studies that were developed before 2019 indicated that VR and AR are gaining more attention in other fields not only in healthcare. However, the different healthcare professionals who generally are working as pharmacists, clinicians and nurses are sufficient to address the use of these VR or AR technologies.

More research has been identified on the potential benefits of the application of these technologies. Furthermore, it is not feasible to develop a specialised curriculum for training in VR that specifically targets particular issues. Instead, it should be comprehensive considering the broader context of healthcare. The combination of clinical knowledge and computer skills is important in this instance and cannot be disregarded in healthcare.

A gap does exist whereby proper work is required to address the methodological approach that can address both the healthcare and computer skills for training healthcare

professionals. Furthermore, only two studies evaluated the expenses associated with the establishment and upkeep of the VR intervention, whereas none of the studies included in the analysis evaluated the cost-effectiveness (Pires, Costa & Dias 2021; Smith et al. 2020). Therefore, it is currently not possible to draw any conclusions on the cost and cost-effectiveness. Insufficient data were available about patient-related outcomes, behaviour change and unintended or detrimental impacts of VR or AR on both patients and those healthcare professionals who are still learning; as a result, this issue requires attention. Studies have shown that the satisfaction results of the adoption of training healthcare professionals using VR or AR are insufficient. It is deemed necessary to establish standardised methods for reporting outcomes on the adoption of VR and AR in healthcare.

Conclusion

The adoption of VR and AR technologies in healthcare is considered the most interesting tools that healthcare should depend on. The training offered for healthcare professionals is generally essential and is based on a specific learning experience. For instance, in a high-risk setting such as the operating room, AR can close the divide between attaining the necessary proficiency and the actual situation. For healthcare professional's clinical training, it is a crucial element in any healthcare curriculum as it provides learners with the opportunity to interact with actual patients in a clinical setting. In addition, patient simulation is an effective method for training healthcare professionals before their clinical experience. It involves the use of patient manikins, which enable learners to develop essential skills and practice without the risk of causing injury to real patients. The utilisation of human practice can be accomplished in a clinical setting or a simulation laboratory. The phrases 'clinical skills lab', 'clinical lab' and 'skills lab' in this work specifically denote methods of patient simulation training.

The main objective of this study is to determine the VR and AR technologies training, which can be effective for healthcare professionals in understanding the required skills and training to provide high-quality work. In addition, the clinical skills lab in healthcare training should provide understanding of the necessary theoretical knowledge and abilities to become proficient and competent professional nurses, ensuring their ability to use and practice these skills safely and successfully. Furthermore, most universities and training facilities, such as colleges, in healthcare implement clinical skills laboratories to enhance the clinical readiness of nursing students.

The study found that VR and AR will provide the healthcare professional opportunities to facilitate a seamless transition to real-life nursing experience by bridging the gap between theoretical knowledge and practical application. Additionally, healthcare professionals can create a secured atmosphere for nursing students to develop and refine the essential skills required in their profession. Therefore, the training and learning become crucial for nursing education to attain positive outcomes and enhance healthcare professional's proficiency, understanding and self-assurance. This study becomes relevant as South Africa is approaching the era of the implementation of National Health Insurance using this type of technologies. It further found that financial implications of procuring and maintaining AR and VR technologies are a significant issue to be addressed by finance committee of the Department of Health (DoH) in rolling out the adoption of these technologies.

Acknowledgements

The authors would like to acknowledge the School of Computing for the post-doctoral fellowship and the University of South Africa for the funding of the project.

Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Authors' contributions

L.M. contributed to conceptualisation, methodology, writing and data curation. B.C. contributed to formal analysis, investigation, writing and funding acquisition.

Funding information

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Disclaimer

The views and opinions expressed in this article are those of the authors and are the product of professional research. The article does not necessarily reflect the official policy or position of any affiliated institution, funder, agency or that of the publisher. The authors are responsible for this article's results, findings and content.

References

Abrams, S.A., Avalos, A., Gray, M. & Hawthorne, K.M., 2020, 'High level of food insecurity among families with children seeking routine care at federally qualified health centers during the coronavirus disease 2019 pandemic', *The journal of pediatrics*: X 4, p. 100044.

Adapa, K., Jain, S., Kanwar, R., Zaman, T., Taneja, T., Walker, J. et al., 2020, 'Augmented reality in patient education and health literacy: A scoping review protocol', *BMJ Open* 10(9), e038416. https://doi.org/10.1136/bmjopen-2020-038416

Alarcon-Urbistondo, P., Perez-Aranda, J. & Casado-Molina, A., 2024, 'Key determinants of intention to use virtual reality in medical training', *Virtual Reality* 28(2), 90. https://doi.org/10.1007/s10055-024-00990-5

Anaraki, N.R., Mukhopadhyay, M., Karaivanov, Y., Wilson, M. & Asghari, S., 2022, 'Living and working in rural healthcare during the COVID-19 pandemic: a qualitative study of rural family physicians' lived experiences', *BMC Primary Care*, 23(1), p. 335.

Azodo, I., Williams, R., Sheikh, A. & Cresswell, K., 2020, 'Opportunities and challenges surrounding the use of data from wearable sensor devices in health care: qualitative interview study', *Journal of Medical Internet Research* 22(10), p. e19542.

Baashar, Y., Alkawsi, G., Wan Ahmad, W.N., Alomari, M.A., Alhussian, H. & Tiong, S.K., 2023, 'Towards wearable augmented reality in healthcare: A comparative survey and analysis of head-mounted displays', *International Journal of Environmental Research and Public Health* 20(5), 3940. https://doi.org/10.3390/ijerph20053940

Bhugaonkar, K., Bhugaonkar, R. & Masne, N., 2022, 'The trend of metaverse and augmented & virtual reality extending to the healthcare system', *Cureus* 14(9), e29071. https://doi.org/10.7759/cureus.29071

Boyles, B., 2017, *Virtual reality and augmented reality in education*, Center For Teaching Excellence, United States Military Academy, West Point, Ny.

Bracq, M.S., Michinov, E. & Jannin, P., 2019, 'Virtual reality simulation in nontechnical skills training for healthcare professionals: a systematic review', *Simulation in Healthcare* 14(3), 188–194.

Brown, P., Waite, F., Lambe, S., Jones, J., Jenner, L., Diamond, R. et al., 2022, 'Automated virtual reality cognitive therapy (gameChange) in inpatient psychiatric wards: Qualitative study of staff and patient views using an implementation framework', *JMIR Formative Research* 6(4), e34225. https://doi.org/10.2196/34225

Buttussi, F., Chittaro, L. & Valent, F., 2020, 'A virtual reality methodology for cardiopulmonary resuscitation training with and without a physical mannequin', *Journal of Biomedical Informatics* 111, 103590. https://doi.org/10.1016/j.jbi.2020.103590

Chang, A.A., Kazemi, E., Esmaeili, V. & Davies, M.S., 2024, 'The effectiveness of virtual reality training: A systematic review', *Journal of Organizational Behavior Management* 44(3), 214–232.

Chung, O.S., Robinson, T., Johnson, A.M., Dowling, N.L., Hg, C.H., Yücel, M. et al., 2022, 'Implementation of therapeutic virtual reality into psychiatric care: Clinicians' and service managers' perspectives', *Frontiers in Psychiatry* 12, 791123. https://doi.org/10.3389/fpsyt.2021.791123

Dehghani, M., Acikgoz, F., Mashatan, A. & Lee, S.H. (Mark), 2022, 'A holistic analysis towards understanding consumer perceptions of virtual reality devices in the post-adoption phase', *Behaviour and Information Technology* 41(7), 1453–1471. https://doi.org/10.1080/0144929X.2021.1876767

Dilanchian, A.T., Andringa, R. & Boot, W.R., 2021, 'A pilot study exploring age differences in presence, workload, and cybersickness in the experience of immersive virtual reality environments', *Frontiers in Virtual Reality* 2, 736793. https://doi.org/10.3389/frvir.2021.736793

Duval, J., Thakkar, R., Du, D., Chin, K., Luo, S., Elor, A. et al., 2022, 'Designing spellcasters from clinician perspectives: A customizable gesture-based immersive virtual reality game for stroke rehabilitation', *ACM Transactions on Accessible Computing* 15(3), 1–25. https://doi.org/10.1145/3530820

Fu, Y., Hu, Y. & Sundstedt, V., 2022, 'A systematic literature review of virtual, augmented, and mixed reality game applications in healthcare', *ACM Transactions on Computing for Healthcare* 3(2), 1–27. https://doi.org/10.1145/3472303

Habibzadeh, H., Dinesh, K., Shishvan, O.R., Boggio-Dandry, A., Sharma, G. & Soyata, T., 2020, 'A survey of healthcare Internet of Things (HIoT): A clinical perspective', *IEEE Internet of Things Journal* 7(1), 53–71. https://doi.org/10.1109/JIOT.2019.2946359

Halbig, A., Babu, S.K., Gatter, S., Latoschik, M.E., Brukamp, K. & von Mammen, S., 2022, 'Opportunities and challenges of virtual reality in healthcare–a domain experts' inquiry', *Frontiers in Virtual Reality* 3, p. 837616.

Han, X., Chen, Y., Feng, Q. & Luo, H., 2022, 'Augmented reality in professional training: A review of the literature from 2001 to 2020', *Applied Sciences* 12(3), 1024. https://doi.org/10.3390/app12031024

Kim, D. & Choi, Y., 2021, 'Applications of smart glasses in applied sciences: A systematic review', *Applied Sciences* 11(11), 4956. https://doi.org/10.3390/app11114956

Li, H., Dong, W., Wang, Z., Chen, N., Wu, J., Wang, G. et al., 2021, 'Effect of a virtual reality-based restorative environment on the emotional and cognitive recovery of individuals with mild-to-moderate anxiety and depression', *International Journal of Environmental Research and Public Health* 18(17), 9053. https://doi.org/10.3390/ijerph18179053

Liaw, S.Y., Ooi, S.L., Mildon, R., Ang, E.N.K., Lau, T.C. & Chua, W.L., 2022, 'Translation of an evidence-based virtual reality simulation-based interprofessional education into health education curriculums: an implementation science method', *Nurse Education Today* 110, p. 105262.

Masood, Z., Qabool, H., Fida, M., Sukhia, R.H. & Fida, M., 2024, 'Exploring the knowledge and awareness on applications of virtual reality and augmented reality technology among dental healthcare professionals – A cross-sectional survey', *Journal of the Pakistan Medical Association* 74(4), S10–S16. https://doi.org/10.47391/JPMA.AKU-9S-03

Noghabaei, M., Heydarian, A., Balali, V. & Han, K., 2020, 'Trend analysis on adoption of virtual and augmented reality in the architecture, engineering, and construction industry', *Data* 5(1), p. 26.

Patel, R., Babady, E., Theel, E.S., Storch, G.A., Pinsky, B.A., St. George, K. et al., 2020, 'Report from the American Society for Microbiology COVID-19 International Summit, 23 March 2020: value of diagnostic testing for SARS–CoV-2/COVID-19', *MBio* 11(2), 10–1128.

Pires, F., Costa, C. & Dias, P., 2021, 'On the use of virtual reality for medical imaging visualization', *Journal of Digital Imaging* 34(4), 1034–1048. https://doi.org/10.1007/s10278-021-00480-z

Quqandi, E., Joy, M., Drumm, I. & Rushton, M., 2023, 'Augmented reality in supporting healthcare and nursing independent learning: narrative review', *CIN: Computers, Informatics, Nursing* 41(5), 281–291.

Ruparel, N., Bhardwaj, S., Seth, H. & Choubisa, R., 2023, 'Systematic literature review of professional social media platforms: Development of a behavior adoption career development framework', *Journal of Business Research* 156, 113482. https://doi.org/10.1016/j.jbusres.2022.113482

Sarkar, U., Lee, J.E., Nguyen, K.H., Lisker, S. & Lyles, C.R., 2021, 'Barriers and facilitators to the implementation of virtual reality as a pain management modality in academic, community, and safety-net settings: Qualitative analysis', *Journal of Medical Internet Research* 23(9), e26623. https://doi.org/10.2196/26623

Singh, B., Vig, K. & Kaunert, C., 2024, 'Modernizing healthcare: Application of augmented reality and virtual reality in clinical practice and medical education', in *Modern technology in healthcare and medical education: Blockchain, IoT, AR, and VR*, pp. 1–21, IGI Global.

Smith, M.J., Graham, A.K., Sax, R., Spencer, E-.S., Razzano, L.A., Smith, J.D. et al., 2020, 'Costs of preparing to implement a virtual reality job interview training programme in a community mental health agency: A budget impact analysis', *Journal of Evaluation in Clinical Practice* 26(4), 1188–1195. https://doi.org/10.1111/jep.13292

Wang, E.Y., Kennedy, K.M., Zhang, L., Qian, D., Forbes, T., Zuniga-Hernande, M. et al., 2023, 'Predicting pediatric healthcare provider use of virtual reality using a technology acceptance model', *JAMIA Open* 6(3), ooad076. https://doi.org/10.1093/jamiaopen/ooad076

Xi, N., Chen, J., Gama, F., Riar, M. & Hamari, J., 2022, 'The challenges of entering the metaverse: An experiment on the effect of extended reality on workload', *Information Systems Frontiers* 25, 659–680. https://doi.org/10.1007/s10796-022-10244-x