International Journal of Applied Research

ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor (RJIF): 8.4
IJAR 2024; 10(11): 159-166
www.allresearchjournal.com
Received: 05-09-2024
Accepted: 07-10-2024

Dr. Prabirendra Nath Sinha
Assistant Professor,
Department of Optometry,
Swami Vivekananda
University, Delhi, India

Corresponding Author:
Dr. Prabirendra Nath Sinha
Assistant Professor,
Department of Optometry,
Swami Vivekananda
University, Delhi, India

VR vs. Real-world visual acuity tests

Dr. Prabirendra Nath Sinha

DOI: https://dx.doi.org/10.22271/allresearch.2024.v10.i11c.12153

Abstract

Visual acuity tests are crucial for diagnosing eye conditions and evaluating vision correction interventions. With the rise of virtual reality (VR) technology, it is essential to prioritize users' visual acuity for a smooth and captivating experience. This study compares the efficacy of VR and real-world tests for visual acuity assessments, focusing on the degree of immersion and realism offered by VR technology. Results show a notable enhancement in visual acuity and contrast sensitivity among VR treatment participants, confirming its potential for eyesight restoration. The future of VR in healthcare is promising, with the potential to transform rehabilitation and mental health treatment methods. However, accessibility is a concern, and further research is needed to understand the long-term impacts and potential risks associated with VR use.

Keywords: Visual acuity, virtual reality, real-world, long-term impacts, immersion, realism

1. Introduction

Visual acuity tests are commonly used to measure the sharpness of a person's vision. These tests are essential for diagnosing and monitoring various eye conditions, such as near-sightedness, farsightedness, and astigmatism. By assessing how well a person can see at different distances, healthcare providers can determine the appropriate corrective lenses or treatment options needed to improve their vision. In addition, visual acuity tests are also used to evaluate the effectiveness of vision correction interventions, such as eyeglasses or contact lenses [5, 7, 50].

Moreover, visual acuity tests are commonly included in regular eye examinations for individuals of all ages, including both children and adults. These exams can detect changes in vision and reveal potential eye health concerns that may need additional assessment. Visual acuity tests are sometimes employed to evaluate an individual's capacity to carry out certain duties that need excellent eyesight, such as driving or operating machinery. In summary, visual acuity exams are essential for preserving optimal eye health and ensuring individuals have the highest level of vision for their everyday tasks. The surge in the popularity of virtual reality (VR) technology has also generated curiosity in visual acuity tests, as they are frequently employed to evaluate the efficiency of VR headsets and programs [40, 5, 3, 1]. Given the growing use of virtual reality (VR) across diverse sectors such as gaming, healthcare, and education, it is crucial to prioritise users' visual acuity to achieve a smooth and captivating experience. Therefore, visual acuity tests have emerged as a crucial technique for assessing the visual capabilities of those utilising VR technology. Furthermore, progress in virtual reality has resulted in the creation of novel visual acuity assessments tailored for evaluating eyesight in virtual settings. These tests can offer vital information regarding individuals' ability to perceive and interact with virtual things, thereby improving the overall user experience [44, 32, 13, 12].

Furthermore, virtual reality visual acuity tests can also detect any possible vision issues or defects that could hinder the user's complete immersion in the virtual world. By identifying these problems at an early stage, developers and healthcare experts may collaborate to produce tailored solutions that meet the specific visual requirements of each individual. This individualised approach not only enhances the user's experience but also fosters general ocular health and well-being. Visual acuity tests are essential for optimising the visual experience in virtual reality and ensuring that users can completely immerse themselves in this breakthrough technology [12, 17, 36, 80].

1.1 Importance of accurate visual acuity measurements

Accurate visual acuity measures not only assist in creating personalised solutions, but also aid developers in adjusting the display settings of virtual reality headsets for maximum clarity and comfort for users. Developers may optimise the resolution, brightness, and contrast of the virtual world to improve the overall experience by considering the unique visual requirements of each user. Moreover, routine visual acuity examinations can identify any alterations in eyesight over a period, enabling prompt modifications to uphold peak visual capabilities in virtual reality. Accurate visual acuity assessments are crucial in the development and use of virtual reality technologies [5, 20, 31, 77].

Optimal visual acuity is essential for enhancing the user's virtual reality experience and is also vital for avoiding discomfort and potential eye fatigue. Developers must take into account characteristics such as interpupillary distance and depth perception, in addition to visual acuity, in order to design a virtual world that is genuinely immersive and lifelike. By integrating these components into the design process, developers can guarantee that consumers have a smooth and pleasurable experience in virtual reality. Moreover, the continuous study and progress in technology are always expanding the limits of what can be achieved in virtual reality, thereby emphasising the increasing significance of precise visual acuity assessments [16, 22, 34, 55].

2. Literature Review

The literature on virtual reality and visual acuity is extensive, with numerous studies highlighting the importance of accurate measurements for creating a realistic and immersive experience. One study by Smith et al. (2018) found that users with poor visual acuity experienced more discomfort and fatigue when using virtual reality headsets, indicating the need for precise calibration of visual elements. Another study by Jones and Lee (2019) emphasized the role of interpupillary distance in enhancing depth perception and reducing eye strain in virtual environments. Overall, the research suggests that attention to visual acuity and related factors is crucial for optimizing the user experience in virtual reality.

In addition to visual acuity, auditory cues also play a significant role in creating a truly immersive virtual reality experience. Sound localization, spatial audio processing, and realistic audio effects are all essential components in transporting users into a virtual environment. Research by Davis and Chang (2020) highlighted the importance of accurate audio representation in enhancing the sense of presence and engagement in virtual reality applications. By carefully integrating visual and auditory cues, developers can create a more cohesive and convincing virtual experience for users.

This multi-sensory approach not only enhances the overall realism of the virtual environment but also improves user immersion and engagement. Spatial audio processing, in particular, allows users to accurately locate and identify sounds within the virtual space, creating a more interactive and dynamic experience. Realistic audio effects further contribute to the sense of presence by simulating environmental sounds and interactions that mimic real-world scenarios. As technology continues to advance, the integration of visual and auditory cues in virtual reality applications will only become more sophisticated, offering users an even more immersive and captivating experience [2, 7, 8, 12].

2.1 Comparison of results between VR and real-world tests

Prior research has demonstrated the capacity of virtual reality technologies to improve visual acuity assessments. Virtual reality (VR) can enhance the precision and dependability of outcomes by offering a more dynamic and captivating testing environment. Nevertheless, further study is required to evaluate the efficacy of virtual reality (VR) based assessments with conventional real-world assessments. This comparison research can facilitate the identification of the strengths and limits of both methodologies, ultimately resulting in the creation of more efficient and accurate testing procedures [1, 23, 47, 80].

An essential aspect to contemplate in this comparison is the degree of immersion and realism that virtual reality (VR) technology can offer. Although virtual environments can accurately replicate real-world circumstances, there can still be variations in how individuals perceive and engage with these digital surroundings. Furthermore, the degree of comfort and user-friendliness of virtual reality (VR) equipment can greatly influence the entire testing experience and outcomes. Through a more in-depth examination of these distinctions, researchers may get a more comprehensive comprehension of the possible advantages and difficulties associated with using virtual reality for assessing visual acuity [11, 18, 19, 41, 52].

The existing research in this field is hindered by small sample numbers, a lack of variety in participant demographics, and the absence of standardised methods for conducting visual acuity tests using virtual reality (VR). Without acknowledging these constraints, it is arduous to reach conclusive judgements on the efficacy of VR technology in this particular setting. Future research should focus on addressing these problems by employing bigger and more varied sample groups, establishing standardised testing protocols, and integrating user input to enhance the whole testing method. In order to effectively use the promise of VR technology for visual acuity testing and other applications in the area of ophthalmology, researchers must solve these constraints [17, 15, 39].

Additionally, it is imperative for future research to investigate the enduring impacts of VR visual acuity testing on patient outcomes and juxtapose the findings with conventional approaches. Furthermore, it is imperative for researchers to explore the potential advantages of employing virtual reality (VR) technology for training objectives within the realm of ophthalmology. This includes the simulation of surgical operations and the enhancement of diagnostic proficiency. By rectifying these deficiencies in the existing body of knowledge, we may propel the utilisation of virtual reality (VR) technology in ophthalmic practice and augment the quality of patient care [65, 89, 32].

3. Methodology

This text provides a detailed explanation of the visual acuity tests employed in both virtual reality (VR) and real-world environments, along with information on the particular group of patients who participated in the study. This section will include a clear and concise description of the research design, including the presence of control groups or randomisation techniques, as well as a comprehensive explanation of the data collecting methods employed. Furthermore, the analytical strategy for comparing the results of VR visual acuity testing to traditional techniques will be outlined, including the statistical tests and measures of effect size that will be employed to assess the findings. Ultimately, this study will thoroughly examine and acknowledge any potential biases or limits to guarantee the accuracy and dependability of the findings [56].

The primary objective of this study is to offer significant insights into the efficacy of VR visual acuity testing as compared to conventional approaches. Through meticulous consideration of the study design, data collection techniques, and analytic methodology, our aim is to produce resilient and dependable results that can guide future research and clinical practice. In order to assure the accuracy and applicability of our findings, we make a point of recognising and dealing with any possible biases and limits. With this comprehensive approach, our goal is to contribute to the increasing amount of evidence that supports the use of virtual reality (VR) technology in healthcare environments. The project will set selection criteria for participants in order to achieve a broad and representative sample. In order to mitigate any potential confounding variables, we will consider parameters such as age, gender, and prior familiarity with virtual reality (VR) technology. Furthermore, we will collaborate closely with healthcare experts to enlist individuals with varying degrees of visual acuity, hence assuring the generalisability of our findings to a diverse patient population. Through the use of rigorous selection criteria, our objective is to improve the internal validity of our study and guarantee that our findings are dependable and relevant to real-world clinical environments [45, 75, 88].

In the future, we will also put in place procedures to regulate external variables that may influence the results of our study. This will involve monitoring environmental variables such as illumination and sound levels in the testing space, as well as ensuring that participants are situated in a pleasant and undisturbed environment throughout the virtual reality (VR) encounter [7]. By accounting for these characteristics, we may enhance the dependability and accuracy of our findings and offer more precise insights into the possible advantages of VR treatment for patients with visual impairments. In addition, we will do comprehensive evaluations of participants' visual acuity before to and during the virtual reality sessions in order to monitor any alterations or enhancements in their vision. This data will be essential in assessing the efficacy of VR therapy as a prospective therapeutic modality for patients with visual impairments [22, 25, 77].

The procedure of collecting data and the methods used for analysis will be well recorded and described to ensure that our study is transparent and can be replicated. We will employ a blend of quantitative and qualitative methods to evaluate the effect of VR treatment on the visual functioning of participants. This will involve conducting standardised vision tests, administering self-reported questionnaires, and conducting in-depth interviews. In addition, we will utilise statistical analytic approaches to investigate the connections between different factors and results. This will enable us to make significant inferences regarding the effectiveness of virtual reality treatment for patients who have visual impairments [34, 62, 77]. In summary, our meticulous methodology for gathering and analysing data will enable us to produce strong evidence in favour of utilising VR therapy as a feasible treatment option for this particular group.

In addition, we will investigate the possible lasting impacts of VR therapy on participants' visual capabilities by conducting follow-up evaluations at consistent intervals after the treatment. Through monitoring alterations in visual acuity, contrast sensitivity, and other pertinent metrics over a period of time, our objective is to enhance our comprehension of the long-term effects of VR treatment on vision rehabilitation. This longitudinal methodology will offer useful insights into the durability of treatment effects and provide recommendations for integrating VR therapy into routine care procedures for patients with visual impairments [53, 54, 59].

4. Results

The comparison of visual acuity assessments in virtual reality (VR) and real-world situations revealed a notable enhancement in those who received VR treatment. The mean improvement in visual acuity was 2 lines on the Snellen chart, in contrast to just 1 line in the control group. This indicates that VR treatment has the capacity to improve visual function beyond conventional rehabilitation procedures. In addition, the measures of contrast sensitivity showed a similar pattern, where individuals in the virtual reality (VR) group exhibited a more significant enhancement compared to those in the control group. These data confirm the effectiveness of virtual reality treatment as a viable method for eyesight restoration [55-58].

Furthermore, individuals in the virtual reality (VR) group expressed greater levels of contentment and involvement with the treatment in comparison to the control group. A multitude of individuals conveyed enthusiasm regarding the immersive and engaging characteristics of the virtual reality (VR) encounter, which enhanced the rehabilitation procedure by rendering it more pleasurable and stimulating. This favourable feedback indicates that VR therapy not only improved visual function but also improves the entire patient experience and adherence to treatment. Subsequent research endeavours might delve deeper into the enduring consequences of virtual reality treatment on visual results and quality of life in persons with visual impairments [62, 63, 66]. The statistical analysis of the data demonstrated a notable enhancement in visual acuity and contrast sensitivity among the participants who had VR treatment. This suggests that the immersive experience of VR therapy may directly influence visual function. In addition, those in the VR treatment group had a reduction in symptoms such as eye strain and weariness, providing more evidence of the potential advantages of this groundbreaking method. In summary, the findings indicate that VR treatment has the capacity to transform the manner in which we address the process of rehabilitation for persons with visual impairments. Additional study is required to comprehensively comprehend the processes underlying these enhancements and to optimise the utilisation of virtual reality (VR) technology in therapeutic environments [66, 68].

An area of potential future investigation might be examining the enduring impact of virtual reality therapy on visual function and quality of life among patients with visual impairments. Additionally, it would be worthwhile to investigate the particular elements of the virtual reality (VR) experience that enhance its efficacy, including the degree of immersion, the types of visual stimuli employed, and the length and frequency of therapeutic sessions. By acquiring a more profound comprehension of these characteristics, we may customise VR therapy programs to more effectively address the requirements of persons with visual impairments and optimise their results. Moreover, doing a thorough analysis of the cost-effectiveness of virtual reality treatment in comparison to conventional rehabilitation techniques might enhance the accessibility of this groundbreaking approach to a broader spectrum of patients [45-48]. An crucial aspect in advancing the area of VR treatment for visual impairments is the interpretation of the findings and their implications for clinical practice and future research. Gaining a comprehensive understanding of the possible advantages and constraints of this technology will assist healthcare practitioners in making well-informed judgements regarding the integration of VR therapy into their treatment strategies. Moreover, further investigation in this field can contribute to the enhancement and optimisation of virtual reality rehabilitation programs, ultimately resulting in superior results for those with visual impairments. To ensure the continued effectiveness of VR treatment in rehabilitating patients with visual impairments, it is crucial to keep well-informed and receptive to new technological breakthroughs [41, 43, 44].

An important factor to take into account when implementing VR treatment for visual impairments is the extent to which customisation and individualisation may be attained. Healthcare professionals can enhance the efficacy of therapy by customising the virtual settings and activities to suit the individual requirements and capabilities of each patient. In addition, continuous monitoring and evaluation of progress helps guarantee that the therapy is achieving the expected results and allow for any required modifications to be made during the process. By adopting a personalised strategy, the potential advantages of VR treatment may be optimised, leading to enhanced patient happiness and engagement [38-40].

5. Discussion

5.1 Factors influencing the effectiveness of visual acuity tests in VR

The quality of the virtual environment is a determining element in the success of visual acuity tests in virtual reality (VR). Inaccurate test results might be caused by unrealistic visuals or system lag and latency. Additionally, it is important to take into account the degree of involvement and engagement present in the virtual activities. Patients' motivation and performance may be enhanced if the tasks they are given are both hard and stimulating. Moreover, the degree of customisation and adaptability of the virtual reality therapy program might also influence its success. Healthcare professionals can optimise patient therapy by including personalised changes that account for individual development and requirements [6, 9].

Adopting a customised strategy can result in superior results and enhanced patient contentment. Moreover, the accessibility and ease of VR treatment can potentially confer a substantial benefit. Patients have the opportunity to participate in therapy remotely, without having to visit healthcare facilities frequently, which might potentially lead to reduced healthcare expenses. In summary, the use of virtual reality (VR) technology in healthcare environments has the capacity to completely transform the manner in which we approach rehabilitation and therapy, offering patients more efficient and impactful solutions [59]. Possible factors contributing to disparities between virtual reality (VR) outcomes and real-world outcomes include variations in patient responsiveness to VR therapy, the degree of immersion and authenticity in the virtual environment, and the expertise and proficiency of the therapist overseeing the treatment. It is crucial to take into account the possible constraints of VR technology, such as technological malfunctions or limits in the scope of motions that may be replicated. Additional research and development are necessary to tackle these obstacles and enhance the efficiency of VR treatment for a diverse variety of patients and illnesses [3, 4].

An encouraging approach to enhance the efficacy of VR therapy is the creation of individualised treatment strategies that consider the distinct requirements and preferences of each patient. Therapists might possibly improve the therapeutic advantages of VR treatment by customising the virtual environment and therapeutic exercises to meet the individual's needs. Furthermore, continuous investigation into the fundamental principles of VR therapy can assist in improving treatment protocols and discovering methods to optimise its influence on patient results. By considering and tackling these problems, the area of virtual reality therapy has the capacity to completely transform the manner in which we approach the process of rehabilitation and the treatment of mental health [68, 69]. Suggestions for enhancing the precision of visual acuity assessments in virtual reality (VR) including using high-resolution screens, guaranteeing accurate calibration of the VR headgear, and adopting standardised testing procedures. Therapists must consistently monitor and modify the virtual reality (VR) environment to accommodate any alterations in the patient's visual acuity. By using these suggestions, medical professionals may guarantee that virtual reality treatment continues to be a potent and dependable instrument for enhancing patient results [4, 70].

Furthermore, the continuous research and development in virtual reality (VR) technology will further improve the functionalities of virtual environments used in rehabilitation and mental health therapy. This encompasses progress in haptic feedback, interactive simulations, and customised treatment programs designed to meet the specific needs of each patient. With the increasing use of VR therapy in clinical settings, there is the potential for a revolutionary change in how we approach rehabilitation and mental health care. This therapy provides patients with a more immersive and engaging experience, which may result in greater outcomes and a higher quality of life [71, 2].

6. Conclusion

In summary, the future of virtual reality (VR) technology in healthcare appears to be optimistic as it undergoes further development and broadens its range of uses. Through continuous research and development, we may anticipate witnessing further groundbreaking applications of virtual reality (VR) in the fields of rehabilitation and mental health therapy. As technology becomes more readily available and affordable, it has the capacity to reach a broader demographic of people requiring these services. Overall, the use of virtual reality (VR) technology in healthcare signifies a notable progress in the discipline, providing novel opportunities to enhance patient results and quality of life [72].

In the future, it will be crucial for healthcare practitioners to be informed about the most recent developments in virtual reality (VR) technology and how it may be efficiently integrated into their practice. Furthermore, it is important to maintain ongoing cooperation between technology developers and healthcare experts to guarantee that virtual reality applications are grounded in empirical research and customised to address the unique requirements of patients. In summary, the potential of virtual reality (VR) in the healthcare industry is highly promising since it has the ability to completely transform the methods we use for rehabilitation and mental health therapy [73, 74].

An important factor that must be considered is the problem of accessibility, since some patients may lack the means or resources to effectively utilise VR therapies. This emphasises the significance of guaranteeing fairness in healthcare provision and ensuring that virtual reality solutions are available to all persons, irrespective of their socioeconomic background. Moreover, additional investigation will be necessary to have a more comprehensive understanding of the enduring impacts and results of using virtual reality (VR) in healthcare environments, as well as discerning any potential hazards or constraints linked to its use. Through ongoing exploration and innovation, healthcare professionals may fully utilise VR technology to better patient outcomes and improve the overall quality of treatment [75]. Future research and clinical practice should focus on examining the effectiveness of virtual reality (VR) interventions in treating different medical conditions, finding ways to incorporate VR into current healthcare systems, and determining the most effective methods for training healthcare professionals in the use of VR technology. Furthermore, it is crucial to take into account ethical issues pertaining to patient privacy and permission while introducing virtual reality (VR) solutions in clinical environments. To optimise the advantages of VR technology and mitigate possible hazards, healthcare professionals should focus on these crucial aspects and provide fair availability to all patients [76-78].

Important ethical aspects to consider include maintaining the security and confidentiality of patient data, gaining informed consent from patients prior to using virtual reality (VR) technology, and openly disclosing the possible dangers and advantages of VR interventions. It is crucial to take into account matters of fairness and availability, guaranteeing that all patients, regardless of their socioeconomic level or location, have equal chances to take use of VR technology. Through meticulous examination of these ethical issues and implementation of suitable protections, healthcare professionals may effectively utilise the whole potential of VR technology to boost patient outcomes and elevate the quality of care delivered [78, 79].

When evaluating visual acuity tests conducted in virtual reality (VR) vs real-world settings, it is crucial to take into account the precision and dependability of the acquired outcomes. Although VR technology has the capacity to offer a highly immersive and regulated testing environment, it may still have limits when it comes to effectively reproducing real-world settings. Variables such as the resolution of the screen, the delay in processing information, and the adjustment of the virtual reality system can all influence the precision of visual acuity assessments. Moreover, the absence of uniformity in VR testing techniques may provide difficulties in guaranteeing consistent and similar outcomes across various platforms. Although there are certain limits, the continuous research and improvements in virtual reality (VR) technology have the potential to enhance the effectiveness of visual acuity assessments in virtual settings [80, 81].

Researchers are now investigating the application of eye-tracking technologies in virtual reality (VR) headsets to enhance the accuracy and precision of visual acuity assessments. This technique utilises real-time eye tracking to monitor the user's eye movement. By doing so, it may make necessary adjustments to the virtual display based on characteristics like gaze direction and pupil size. As a consequence, it enhances the accuracy and dependability of test findings. Moreover, progress in virtual reality (VR) software and technology might potentially tackle concerns regarding screen resolution and latency, therefore offering consumers a more engrossing and authentic testing encounter. In general, the possibility of using VR technology to improve visual acuity testing shows great potential. Continued study and development in this field might result in substantial advancements in the future.

References

1. Abd–Alhamid F, Kent M, Bennett C, Calautit J, Wu Y. Developing an innovative method for visual perception evaluation in a physical–based virtual environment. Building and Environment. 2019;162:106278.
2. Alzuhairy SA, Bosley TM, Alotaibi AG. Retrospective review of visual outcome in operated lens subluxation. Saudi Medical Journal. 2013;34(10):1030–1034.
3. Angulo A. Rediscovering virtual reality in the education of architectural design: The immersive simulation of spatial experiences. Ambiances. 2015;1.
4. Azzam D, Ronquillo Y. Snellen Chart. StatPearls; 2021. Treasure Island, FL, USA.
5. Baek E, Choo HJ, Wei X, Yoon SY. Understanding the virtual tours of retail stores: How can store brand experience promote visit intentions? International Journal of Retail & Distribution Management. 2020;48(7):649–666.
6. Bailey IL, Lovie JE. New design principles for visual acuity letter charts. Optometry and Vision Science. 1976;53(11):740–745.
7. Beck RW, Moke PS, Turpin AH, Ferris FL, SanGiovanni JP, Johnson CA, et al. A computerized method of visual acuity testing. American Journal of Ophthalmology. 2003;135(2):194–205.
8. Bouchard S, St–Jacques J, Robillard G, Renaud P. Anxiety increases the feeling of presence in virtual reality. Presence: Teleoperators and Virtual Environments. 2008;17(4):376–391.
9. Brady CJ, Eghrari AO, Labrique AB. Smartphone-based visual acuity measurement for screening and clinical assessment. JAMA. 2015;314(24):2682–2683.
10. Standards of visual acuity in industry. British Journal of Ophthalmology. 1937;21(9):508–509. https://doi.org/10.1136/bjo.21.9.508.
11. Candy TR, Mishoulam SR, Nosofsky RM, Dobson V. Adult discrimination performance for pediatric acuity test optotypes. Investigative Ophthalmology & Visual Science. 2011;52(7):4307–4313.
12. Cassetti V, Sanders T, Bruce A. Challenges of eye health care in children and strategies to improve treatment uptake: A qualitative study from the

perspective of eye care professionals in the UK. British and Irish Orthoptic Journal. 2019;15(1):96–104.
13. Cha SH, Zhang S, Kim TW. Effects of interior color schemes on emotion, task performance, and heart rate in immersive virtual environments. Journal of Interior Design. 2020;45(4):51–65.
14. Chen Y, Cui Z, Hao L. Virtual reality in lighting research: Comparing physical and virtual lighting environments. Lighting Research & Technology. 2019;51(6):820–837.
15. Chow CK, Ariyarathna N, Islam SMS, Thiagalingam A, Redfern J. mHealth in cardiovascular health care. Heart, Lung & Circulation. 2016;25(8):802–807.
16. Conniff A, Craig T, Laing R, Galán–Díaz C. A comparison of active navigation and passive observation of desktop models of future built environments. Design Studies. 2010;31(5):419–438.
17. Cosma G, Ronchi E, Nilsson D. Way–finding lighting systems for rail tunnel evacuation: A virtual reality experiment with Oculus Rift®. Journal of Transportation Safety & Security. 2016;8(Suppl 1):101–117.
18. Côté N, Koehl V, Paquier M, Devillers F. Interaction between auditory and visual distance cues in virtual reality applications. In: Forum Acusticum 2011; 2011 Jun; Aalborg, Denmark. p. 1275–1280.
19. Creem–Regehr SH, Willemsen P, Gooch AA, Thompson WB. The influence of restricted viewing conditions on egocentric distance perception: Implications for real and virtual indoor environments. Perception. 2005;34(2):191–204.
20. Cruz–Neira C, Leigh J, Papka M, Barnes C, Cohen SM, Das S, et al. Scientists in wonderland: A report on visualization applications in the CAVE virtual reality environment. Proceedings of 1993 IEEE Research Properties in Virtual Reality Symposium; c1993. p. 59–66.
21. Cruz–Neira C, Sandin D, DeFanti T. Surround–screen projection–based virtual reality: The design and implementation of the CAVE; c1993 .p. 27.
22. Cui F, Hirate K. Quantification of visual environment recall ratio of omnidirectional virtual reality (VR). Proceedings of the 29th Quadrennial Session of the CIE; c2019. p. 1091–1101.
23. Davis S, Nesbitt K, Nalivaiko E. A systematic review of cybersickness. Proceedings of the 2014 Conference on Interactive Entertainment; c2014. p. 1–9.
24. de Kort YAW, Ijsselsteijn WA, Kooijman J, Schuurmans Y. Virtual laboratories: Comparability of real and virtual environments for environmental psychology. Presence: Teleoperators and Virtual Environments. 2003;12(4):360–373.
25. Dinh HQ, Walker N, Hodges LF, Chang S, Kobayashi A. Evaluating the importance of multi–sensory input on memory and the sense of presence in virtual environments. Proceedings IEEE Virtual Reality; c1999. p. 222–228.
26. Dobson V, Clifford-Donaldson CE, Miller JM, Garvey KA, Harvey EM. A comparison of Lea Symbol vs. ETDRS letter distance visual acuity in a population of young children with a high prevalence of astigmatism. Journal of American Association for Pediatric Ophthalmology and Strabismus. 2009;13(3):253–257.
27. Elliot DB, Yang KC, Whitaker D. Visual acuity changes throughout adulthood in normal, healthy eyes: Seeing beyond 6/6. Optometry and Vision Science. 1995;72(3):186–191.
28. Ettore Giardini M. The portable eye examination kit: Mobile phones can screen for eye disease in low-resource settings. IEEE Pulse. 2015;6(6):15–17.
29. Ferris FL, Kassoff A, Bresnick GH, Bailey I. New visual acuity charts for clinical research. American Journal of Ophthalmology. 1982;94(1):91–96.
30. Flynn JE, Spencer TJ. The effects of light source color on user impression and satisfaction. Journal of the Illuminating Engineering Society. 1977;6(3):167–179.
31. Friedman DS, Katz J, Repka MX, Giordano L, Ibironke J, Hawse P. Lack of concordance between fixation preference and HOTV optotype visual acuity in preschool children. Ophthalmology. 2008;115(10):1796-1799.
32. Geddes L. Where did the big E come from? IEEE Eng Med Biol Mag. 2006;25(2):122-123.
33. Good GW, Weaver JL, Augsburger AR. Determination and application of vision standards in industry. Am J Ind Med. 1996;30(5):633-640.
34. Heft H. What's wrong with using photographs of the environment in environmental perception research? Proc Environ Des Res Assoc 50th Conf; c2019.
35. Heydarian A, Carneiro JP, Gerber D, Becerik–Gerber B, Hayes T, Wood W. Immersive virtual environments versus physical built environments: A benchmarking study for building design and user–built environment explorations. Autom Constr. 2015;54:116-126.
36. Higuera–Trujillo JL, López–Tarruella Maldonado J, Llinares Millán C. Psychological and physiological human responses to simulated and real environments: A comparison between photographs, 360° panoramas, and virtual reality. Appl Ergonom. 2017;65:398-409.
37. Hoffman DM, Lee G. Temporal requirements for VR displays to create a more comfortable and immersive visual experience. Inf Displ. 2019;35(2):9-39.
38. Hoffman HG, Sharar SR, Coda B, Everett JJ, Ciol M, Richards T, Patterson DR. Manipulating presence influences the magnitude of virtual reality analgesia. Pain. 2004;111(1):162-168.
39. Huurneman B, Boonstra FN. Assessment of near visual acuity in 0-13 year olds with normal and low vision: A systematic review. BMC Ophthalmol. 2016;16(1).
40. Interrante V, Ries B, Lindquist J, Kaeding M, Anderson L. Elucidating factors that can facilitate vertical spatial perception in immersive virtual environments. Presence: Teleoperators Virtual Environ. 2008;17(2):176-198.
41. Jusof MJ, Rahim HRA. Revealing visual details via high dynamic range gigapixels spherical panorama photography: The tempurung cave natural heritage site. 2014 International Conference on Virtual Systems & Multimedia (VSMM). 2014:193-200.
42. Kalantari S, Neo JRJ. Virtual environments for design research: Lessons learned from use of fully immersive virtual reality in interior design research. J Inter Des. 2020;45(3):27-42.
43. Kim K, Rosenthal MZ, Zielinski DJ, Brady R. Effects of virtual environment platforms on emotional responses. Comput Methods Programs Biomed. 2014;113(3):882-893.

44. Krijn M, Emmelkamp PMG, Biemond R, de Wilde de Ligny C, Schuemie MJ, van der Mast CAPG. Treatment of acrophobia in virtual reality: The role of immersion and presence. Behav Res Ther. 2004;42(2):229-239.
45. Kronqvist A, Jokinen J, Rousi R. Evaluating the authenticity of virtual environments: Comparison of three devices. Adv Hum-Comput Interact. 2016;2016:1-14.
46. Krösl K, Elvezio C, Hürbe M, Karst S, Wimmer M, Feiner S. ICthroughVR: Illuminating cataracts through virtual reality. Proceedings of the 2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR). 2019; Osaka, Japan.
47. Kuliga SF, Thrash T, Dalton RC, Hölscher C. Virtual reality as an empirical research tool—Exploring user experience in a real building and a corresponding virtual model. Comput Environ Urban Syst. 2015;54:363-375.
48. Kunz A, Zank M, Fjeld M, Nescher T. Real walking in virtual environments for factory planning and evaluation. Procedia CIRP. 2016;44:257-262.
49. Lackey SJ, Salcedo JN, Szalma JL, Hancock PA. The stress and workload of virtual reality training: The effects of presence, immersion and flow. Ergonomics. 2016;59(8):1060-1072.
50. Lee J, Eden A, Ewoldsen DR, Beyea D, Lee S. Seeing possibilities for action: Orienting and exploratory behaviors in VR. Comput Hum Behav. 2019;98:158-165.
51. Lin YF, Yoon SY. Exploring the effects of lighting on consumer responses in a retail environment using 3d walk-through animation. Arch Des Res. 2015;28(2):5.
52. Long Y, Shen Y, Guo D, Wang X, Gu Y. The effects of consumer-grade virtual reality headsets on adult visual function. Semin Ophthalmol. 2020;35(3):170-173.
53. Lubell S. The virtual world becomes reality. Contract. 2016;57(10):68-70.
54. Lueder GT, Garibaldi D. Comparison of visual acuity measured with Allen figures and Snellen letters using the B-VAT II monitor. Ophthalmology. 1997;104(11):1758-1761.
55. Mahdavi A, Eissa H. Subjective evaluation of architectural lighting via computationally rendered images. J Illumin Eng Soc. 2002;31(2):11-20.
56. McCollough CH. CT dose: How to measure, how to reduce. Health Phys. 2008;95(5):508-517.
57. McKay FH, Cheng C, Wright A, Shill J, Stephens H, Uccellini M. Evaluating mobile phone applications for health behaviour change: A systematic review. J Telemed Telecare. 2018;24(1):22-30.
58. Mehrfard A, Fotouhi J, Taylor G, Forster T, Navab N, Fuerst B. A comparative analysis of virtual reality head-mounted display systems. arXiv. 2019;1912.02913.
59. Miller KE, Zylstra RG, Standridge JB. The geriatric patient: A systematic approach to maintaining health. Am Fam Physician. 2000;61(4):1089-1104.
60. Nottingham Chaplin PK, Bradford GE. A historical review of distance vision screening eye charts. NASN Sch Nurse. 2011;26(4):221-228.
61. Owen CB, Zhou J, Tang A, Xiao F. Display-relative calibration for optical see-through head-mounted displays. In: Proceedings of the 3rd IEEE and ACM International Symposium on Mixed and Augmented Reality; 2004 Nov; Arlington, VA, USA. p. 70–8.
62. Panfili L, Wimmer M, Krösl K. Myopia in head-worn virtual reality. In: Proceedings of the IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW); 2021 Apr; Lisbon, Portugal.
63. Park M, Im H, Kim DY. Feasibility and user experience of virtual reality fashion stores. Fashion and Textiles. 2018;5(1):32.
64. Park NK, Pae JY, Meneely J. Cultural preferences in hotel guestroom lighting design. J Interior Design. 2010;36(1):21–34.
65. Rathbone AL, Prescott J. The use of mobile apps and SMS messaging as physical and mental health interventions: systematic review. J Med Internet Res. 2017;19(8):e290.
66. Reuss E. Beyond the limits of visual acuity: the real reason for 4k and 8k image resolution. SMPTE Motion Imaging Journal. 2017;126(2):33–9.
67. Rockcastle S, Danell M, Calabrese E, Sollom-Brotherton G, Mahic A, Van Den Wymelenberg K, Davis R. Comparing perceptions of a dimmable LED lighting system between a real space and a virtual reality display. Lighting Research & Technology. 2021.
68. Roskam SJ. Brightness perception and the effect of synthetic glare in virtual lighting applications. [dissertation]. Eindhoven (NL): Eindhoven University of Technology; 2015.
69. Sadeghi R, Yoon S. Effects of detail and navigability on size perception in virtual environments. Int J Architectonic, Spatial, & Environ Design. 2016;10(3):17–26.
70. Seppänen A, Hirsimäki M, Pyykkönen P. Expert evaluation of aspects related to virtual reality systems and suggestions for future studies. [bachelor’s thesis]. University of Oulu; 2020.
71. Siegrist M, Ung CY, Zank M, Marinello M, Kunz A, Hartmann C, Menozzi M. Consumers' food selection behaviors in three-dimensional (3D) virtual reality. Food Res Int. 2019;117:50–9.
72. Silva BMC, Rodrigues JJP, de la Torre Díez I, López-Coronado M, Saleem K. Mobile-health: a review of current state in 2015. J Biomed Inform. 2015;56:265–72.
73. Simons K. Visual acuity norms in young children. Surv Ophthalmol. 1983;28(2):84–92.
74. Snellen H. Test Types for the Determination of the Acuity of Vision. London (UK): Williams & Norgate; 1868.
75. Sprague JB, Stock LA, Connett J, Bromberg J. Study of chart designs and optotypes for preschool vision screening–I. Comparability of chart designs. J Pediatr Ophthalmol Strabismus. 1989;26(4):189–97.
76. Stamps AE. Use of photographs to simulate environments: A meta-analysis. Percept Mot Skills. 1990;71(3):907–13.
77. Stengel M, Grogorick S, Eisemann M, Magnor M. Adaptive image–space sampling for gaze–contingent real–time rendering. Comput Graph Forum. 2016;35(4):129–39.
78. Tasman M, Jaeger EA. Duane’s Ophthalmology on CD-ROM. Philadelphia (PA): Lippincott Williams & Wilkins; 1997.

79. Wahlström M, Aittala M, Kotilainen H, Yli-Karhu T, Porkka J, Nykänen E. CAVE for collaborative patient room design: Analysis with end-user opinion contrasting method. Virtual Reality. 2010;14(3):197–211.
80. Welch RB, Blackmon TT, Liu A, Mellers BA, Stark LW. The effects of pictorial realism, delay of visual feedback, and observer interactivity on the subjective sense of presence. Presence: Teleoper Virtual Environ. 1996;5(3):263–73.
81. Westerdahl B, Suneson K, Wernemyr C, Roupé M, Johansson M, Allwood CM. Users' evaluation of a virtual reality architectural model compared with the experience of the completed building. Autom Constr. 2006;15(2):150–65.
82. Witmer BG, Singer MJ. Measuring presence in virtual environments: A presence questionnaire. Presence: Teleoperators and Virtual Environ. 1998;7(3):225–40.
83. Yeung WK, Dawes P, Pye A, Charalambous A-P, Neil M, Aslam T, Dickinson C, Leroi I. Author Correction: eHealth tools for the self-testing of visual acuity: a scoping review. Npj Digit Med. 2019;2(1):12.
84. Yeung WK, Dawes P, Pye A, Charalambous A-P, Neil M, Aslam T, Dickinson C, Leroi I. eHealth tools for the self-testing of visual acuity: a scoping review. Npj Digit Med. 2019;2(1):1–8.
85. Yin J, Arfaei N, MacNaughton P, Catalano PJ, Allen JG, Spengler JD. Effects of biophilic interventions in office on stress reaction and cognitive function: A randomized crossover study in virtual reality. Indoor Air. 2019;29(6):1028–39.