A Systematic Review of Purpose and Latency Effect in the Virtual Reality Environment

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Abstract. VR means immersing oneself in a virtual environment where all we see is three dimensional (3D) computer-generated. VR has been around for several decades now, but in recent years, the consistency of experience has dramatically improved. This technology has been recognised worldwide, making the adoption of VR a more progressive widespread occurrence across various fields. VR technology evolves very fast and significant as it merges with artificial intelligence (AI), thus transforming the way people use machines and smartphones in daily life to communicate with the world around them. However, there is a problem commonly faced by the virtual reality user, which is cybersickness or motion sickness in the virtual reality environment. As the result, a systematic review has been made to gain a better understanding and present this information in the form of a written summary of current researches. The study of the previous research publication of review papers was limited around 2017 to 2021 from the Scopus library. Among 187 results, five of them were selected since they met the criteria through the inclusion and exclusion criteria procedure. Eight purposes were found and listed together with the outcomes. This paper also briefly discusses the latency effect and its relationship with motion sickness in the virtual reality environment and system. Understanding the purpose and latency effect in the virtual reality environment can encourage researchers and developers to find a better solution to counter the motion sickness problem.

Keywords: Virtual reality · Motion sickness · System latency

1 Introduction

Within the last few years, researchers have been focusing on the area known as virtual reality. This technology, which comes out with an interactive computer-generated environment, has moved from being focused on gaming to professional development [1]. Although the augmented reality (AR) technology is also one of the most famous and popular multimedia technology [2], it also has a high reputation and well-known across the globe. Recent developments in the field of virtual reality have led to a renewed

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interest in many industries from many sectors including education, military, business, medical, agriculture, tourism, and transport. In 1987, the first definition of virtual reality formulated by Jaron Lanier and Steve Bryson described that the use of computer technology to create the illusion of an immersive three-dimensional world in which objects have a sense of spatial presence is known as virtual reality [3].

Experiencing virtual reality technology requires a system with specifically designed computer software that can implement the technology and a head-mounted display (HMD) that allow users to see the virtual environment. The first HMD was invented and developed in Sutherland in 1965, which was introduced as the ultimate display [4] and became available to the public commercially as the revival of virtual reality with HMD at a low price [5]. Many HMDs have been produced by multiple gigantic companies like Google, HTC, Facebook, Sony, and Samsung, allowing users to experience immersive virtual reality with the presence of advanced virtual assisted tools and devices like the Oculus head-mounted display [6].

Nowadays, virtual reality technology is used for various purposes and applications. More importantly, this technology is still able to be developed further from time to time. The latency effect plays a bigger part in virtual reality. By understanding the latency effect in virtual reality, the most common diseases experienced by virtual reality users can be reduced. Thus, virtual reality will have the opportunity to grow and expand beyond the initial creation.

Much research has been conducted to extend the body of knowledge in this domain. However, there are some grey areas with the existing knowledge of virtual reality. One major theoretical issue that has dominated the field for many years concerns the motion sickness effect in virtual reality. It is also known as cybersickness in terms of symptoms as they are similar. The only difference between the terms is that motion sickness is caused in the real world while cybersickness is caused by the virtual one [7].

This paper summarises recent review papers on the virtual reality subject in terms of usage purposes and outcomes of the research in their specific fields. Nonetheless, there is a newer trend regarding this domain that exists and has yet to be reviewed.

2 Past Review

The goal of this chapter is to study, evaluate, and classify the existing works of the past review on the same field. By performing the systematic literature review method (SLR) commonly used by today's reviewers, five publications related to the study were found. This research used a particular string to search for a published review paper in the popular database journal named Scopus, which was set as the title. The string included "systematic review" AND "virtual reality" results in 187 documents. To filter the article for further investigation, this research utilised several inclusion and exclusion criteria. Table 1 and Table 2 below show the criteria in the inclusion and exclusion process.

From the inclusion and exclusion filtration procedure, five publication were selected to be reviewed as they met the criteria above besides being related to the field of study. Table 3 illustrates the summary of five selected papers classified into three subjects; the title, author, as well as purpose and outcome.

Table 1. Inclusion criteria

	Inclusion
1	Publication from 2017 to 2021
2	Keywords: virtual reality, systematic review, review, meta-analysis
3	Articles written in English

Table 2. Exclusion criteria

	Exclusion
1	Articles not related to motion sickness approaches
2	Articles with a similar region of review

Table 3. The previous research summary

	Title	Author	Purpose	Outcome
1	A systematic literature review on virtual reality for learning [8]	Kurniawan, C, et al. (2019)	a) To understand how virtual reality can be used to enhance learning	a) There are four purposes for using VR in learning, which are to improve participants' achievement, enhance the learning, engaging, and motivate the participants b) Two types of devices are used for VR learning, namely, projection divided into a personal and large screen, and an interaction type divided into tracking, haptics, and audio c) Two types of user experience in VR learning, which are single and multi-users. The single-user is the most used for user experience

(*continued*)

Table 3. (*continued*)

	Title	Author	Purpose	Outcome
2	A systematic review of immersive virtual reality applications for higher education: design elements, lessons learnt, and research agenda [9]	J.Radianti, et al. (2019)	a) To identify the design elements of existing research focusing on the application of VR in higher education	a) Learning theory is often not considered in VR application development to accomplish the learning outcome b) VR is still experimental in most domains with the usage that is considered unsystematic c) Acknowledgement about VR application that has been used on the regular basis in some domains, especially for practical knowledge
3	The new era of virtual reality locomotion: a systematic literature review of techniques and a proposed typology [10]	Boletsis, C (2017)	a) An analysis of the literature on the modern age of virtual reality locomotion strategies, which has been studied since 2014 b) Proposed a typology for VR locomotion technique	a) The study of virtual reality locomotion focusing on the physical movement needs to navigate open virtual worlds in continuous motion b) An empirical study is needed with approaches under comparative arrangements
4	A systematic review of a virtual reality system from the perspective of user experience [11]	Y.M. Kim, et al. (2019)	a) To provide a structured methodology to categorise current virtual reality studies b) To categorise and summarise research on user experience in virtual reality c) To state the current limitations for future advancement and development	a) The study of user experiences in virtual reality requires more research, especially into virtual reality device-related issues and technology, as well as the research methodology b) There are bad effects that may not be confirmed in the VR context and yet to be introduced c) Study on utilising the sensor data on virtual reality system might lack performance

(*continued*)

Table 3. (*continued*)

	Title	Author	Purpose	Outcome
5	The use of virtual reality simulation among nursing students and registered nurses: A systematic review [12]	Shorey, S, et al. (2021)	a) To investigate and evaluate the latest evidence on the use of virtual reality as a teaching tool	a) Virtual reality is mostly studied by nursing students and in developed countries b) Virtual reality is budget-saving and saves time compared to mannequin simulation and lectures c) Virtual reality is lack of realistic presence and often has technological issues

Virtual reality is one of the most anticipating domains in research because the technology evolves dramatically throughout the years and still ongoing. The search was carried out using Scopus for systematic literature. Figure 1 displays the publication trends included since 2007 in this review. A significant increase in the number of articles can be seen every year until 2020. Following that, a downtrend to less than 10 publications was observed by the year 2021.

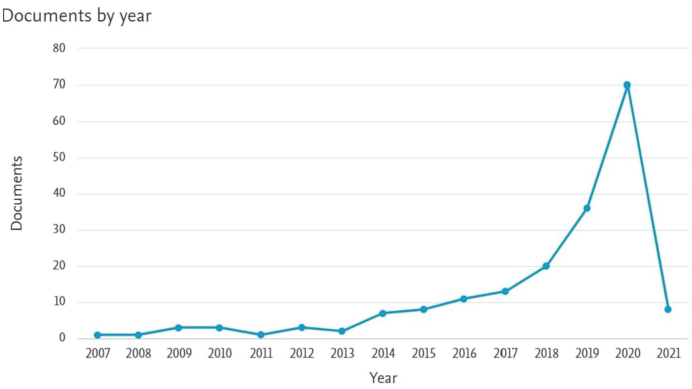

Fig. 1. Document publication trends (Source: Scopus)

From the same source, the documents related to the virtual reality domain came from various types. According to the comparison in Fig. 2, documents published were dominated by reviews, which accounted for 60.4% in the Scopus database, followed by articles, which accounted for 29.4%, and conference papers representing 4.8%.

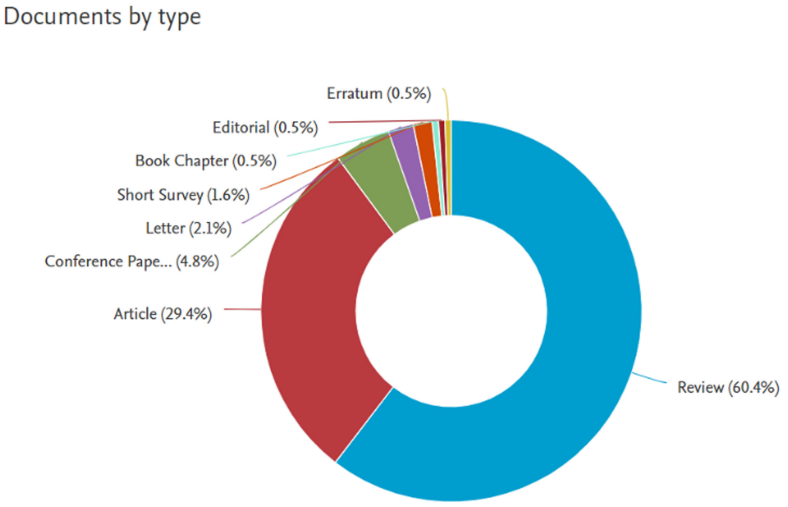

Fig. 2. Document publication trends (Source: Scopus)

In addition, Scopus shows document publications according to the subject area. It was reported that the highest subject area involves medicine with 37.6%. The health professions took second place with 10.9% while computer science came third with 9% in their database. Figure 3 illustrates the comparison among documents published by subject area.

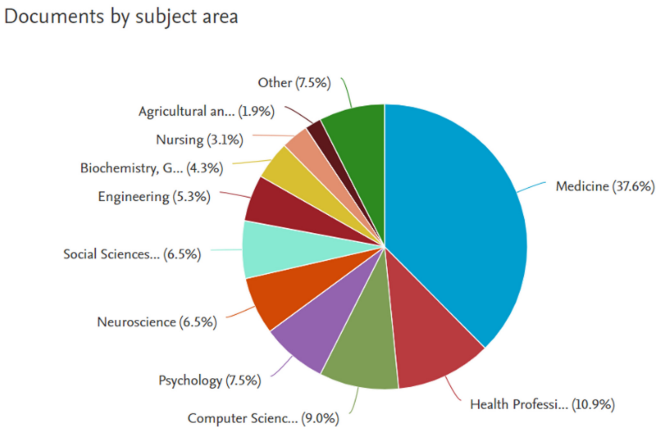

Fig. 3. Document publication comparison by subject area (Source: Scopus)

3 System Latency in VR

Latency is the time taken for a system to react to the actions of the user. The primary factor of the lessened sense of presence is latency in HMD systems [13]. Virtual reality technology can potentially grow further in interacting with computers. However, there are still some disadvantages such as motion sickness and discomfort to the user [14]. Jason (2009) defined the virtual environment as 'Immersive Virtual Environment' (IVE) with the additional requirement that only computer-generated visual cues are visible and divide the IVE system into their primary components: tracking, application, rendering, and display [15]. Figure 4 shows the loop process between the user and the IVE system. The tracking will calculate the user's perspective. Non-rendering aspects of the virtual world are included in the application, such as updating dynamic geometry, user interaction other than perspective manipulation, and physics simulation. The geometric description will transform into a pixel in rendering. The process of the display shows the computed pixel physically to the user from a video signal.

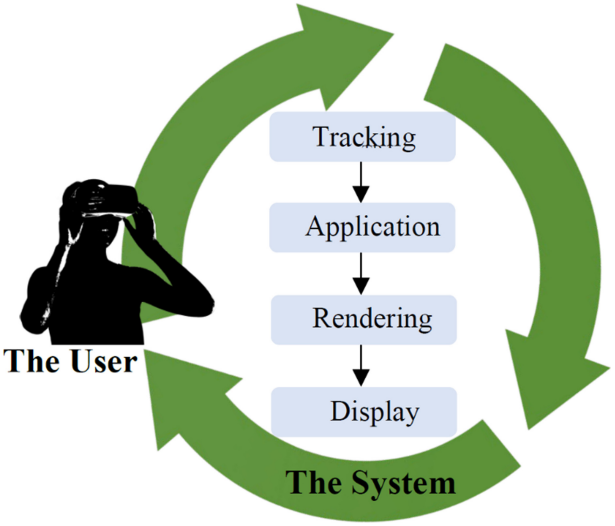

Fig. 4. An immersive virtual environment system consisting of the input from the user that will go through four primary components and produce output to the user.

4 Motion Sickness in Virtual Reality Environment

Motion sickness is produced by motion. Other motions like visual or vehicle motion come from motion sickness in the virtual reality environment. These motions are the contributors to cybersickness [16]. According to Nesbitt K. et al. (2018) "Cybersickness is an uncomfortable side effect experienced by users of immersive interfaces commonly used for Virtual Reality. It is associated with symptoms such as nausea, postural instability, disorientation, headaches, eye-strain, and tiredness." [17]. Some people experience

motion sickness in VR, which means that when they put on a headset and enter a virtual world, they feel dizzy or nauseous. Eye fatigue disorientation and nausea are the major signs of VR sickness (Joseph et al., 2000) [18]. These uncomfortable feelings will inhibit future experiences of VR; thus, these problems require an urgent solution.

One of the previous researchers discovered that motion sickness is caused by visual motion in virtual reality [19]. Similar symptoms of motion sickness also came from the lower frame per second of the virtual reality display (FPS). According to Cheng Zang (2020), if the frame per second is limited to below 50 Hz, the user may experience uncomfortable side effects of the virtual reality motion sickness [20]. In addition, the most essential and yet one of the factors that caused the motion sickness effect is the content. Chang E. et al. (2020) stated that the degree of VR constancy and virtual reality sickness is determined by the material used in virtual reality. With developers striving for higher constancy in VR, the content's specifics are becoming more complicated [21].

Despite many factors that contribute to motion sickness in the virtual reality environment, various solutions can reduce the motion sickness effect on users. One of the solutions is using the teleportation technique instead of navigating technique that uses more head movement to complete a task. By teleporting, the user can get a more pleasant experience in virtual reality [22]. Besides, the efficiency of VR is largely determined by its hardware. To deliver content to a user as intended by the developer, a particular hardware specification must be supported [21].

5 Virtual Reality System

In the virtual environment, users can use their eyes, ears, and their hands just like they normally do in the real world to perform virtual interaction [23]. A system needs to allow the users to experience virtual reality. It also cultivates self-determination theory (SDT), a motivation by supporting users' intrinsic tendency to behave in an effective way [2].

The VR system consists of three classified categories, namely non-immersive, immersive, and semi-immersive [24]. The non-immersive provides a less immersive experience compared to the other two. The user can interact with the environment by using only a mouse and joystick [25]. A video game is the best example of a non-immersive environment. The semi-immersive uses the hybrid system and plays a substitute role but not for replacing reality [26]. This type of environment is frequently used for training purpose [27]. For example, the flight simulation. Meanwhile, the immersive category provides the highest experience of immersive virtual reality [24]. For example, the head-mounted display (HMD) device or fully equipped virtual reality room. The Table 4 below shows the virtual reality system category with details and tools.

Table 4. Virtual reality system category

	Category	Detail	Tools
1	Non-Immersive	-Least immersive -Least sophisticated component	-3D environment stereo display monitor or glass
2	Immersive	-Most expensive -Highest level immersion -Feeling of being in a virtual environment (VE)	-Head-mounted display (HMD) -Tracking device -Data glove
3	Semi-Immersive	-A hybrid system or augmented reality -High-level immersion	-Desktop virtual reality -Some physical models

6 Conclusion

This systematic review identified eight purposes for conducting the research related to virtual reality. Among the eight, six of them contributed clear findings to the research while the other two have provided the idea and insight that will help to maintain the relevance of virtual reality technology. This study has also explained the latency effect of the virtual reality environment and its relation with motion sickness and virtual reality system. Each relationship focuses on the definition to provide a better understanding of virtual reality. Understanding the purpose and the latency effect in a virtual reality environment can motivate researcher and developer to achieve a better solution and technique to overcome or at least minimise the motion sickness in virtual reality environment.

Virtual reality technology takes the next advanced step in human-machine interaction. This study proved that virtual reality could provide a massive contribution to many regions and society besides possibly breach a new discovery. Moreover, this study also found some boundaries and limitations to fully utilise the technology to meet their purposes. This study also found that the current findings need to be further studied from every aspect. Modern technology tends to evolve dramatically, but virtual reality technology is believed to possibly maintain its relevance in the future for many years.

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References

1. Kamińska, D., et al.: Virtual reality and its applications in education: survey. Information (Switzerland) **10**(10), 318 (2019)
2. Shamsuddin, S., Selman, M., Ismail, I., Amin, M., Rawi, N.: A conceptual framework for gamified learning management system for LINUS students. Indonesian J. Electr. Eng. Comput. Sci. **12**(3), 1380–1385 (2018)

3. Bryson, S.: Virtual Reality: A Definition History - A Personal Essay, December 2013. https://arxiv.org/abs/1312.4322. Author, F.: Contribution title. In: 9th International Proceedings on Proceedings, pp. 1–2. Publisher, Location (2010)
4. LNCS Homepage. http://www.springer.com/lncs. Accessed 21 Nov 2016. Sutherland, I.E.: The ultimate display. In: Multimedia: From Wagner to Virtual Reality, pp. 506–508. Macmillan and Co, London (1965)
5. Wang, J., Lindeman, R.: Coordinated hybrid virtual environments: seam-less interaction contexts for effective virtual reality. Comput. Graph. **48**, 71–83 (2015)
6. Zolkefly, N.N., Ismail, I., Safei, S., Shamsuddin, S.N.W., Arsad, M.A.M.:. Head gesture recognition and interaction techniques in virtual reality: a review. Int. J. Eng. Technol. (UAE) **7**(4.31 Special Issue 31), 437–440 (2018)
7. Martirosov, S., Kopecek, P.: Cyber sickness in virtual reality- literature review. In: Katalinic, B. (ed.) Proceedings of the 28th DAAAM International Symposium, Vienna, Austria, pp. 0718–0726, Published by DAAAM International, ISBN 978-3-902734-11-2, ISSN 1726-9679 (2017)
8. Kurniawan, C., Rosmansyah, Y., Dabarsyah, B.: A systematic literature review on virtual reality for learning. In: Proceeding of 2019 5th International Conference on Wireless and Telematics, ICWT 2019. Institute of Electrical and Electronics Engineers Inc. (2019)
9. Radianti, J., Majchrzak, T.A., Fromm, J. et al.: A systematic review of immersive virtual reality applications for higher education: design elements, lessons learned, and research agenda. Comput. Educ. (2019)
10. Kim, Y.M., Rhiu, I., Yun, M.H.: A systematic review of a virtual reality system from the perspective of user experience. Int. J. Hum. Comput. Interact. **36**(10), 893–910 (2019)
11. Boletsis, C.: The new era of virtual reality locomotion: a systematic literature review of techniques and a proposed typology. Multimodal Technol. Interact. **1**(4), 24 (2017)
12. Shorey, S., Ng, E.D.: The Use of virtual reality simulation among nursing students and registered nurses: A systematic review. Nurse Education Today. Churchill Livingstone (2020)
13. Meehan, M., Brooks, F., Razzaque, S., Whitton, M.: Effects of latency on presence in stressful virtual environments. In: Proceedings of IEEE Virtual Reality, pp. 141–148 (2003)
14. Davis, S., Nesbitt, K., Nalivaiko, E.: A systematic review of cybersickness. In: IE 2014. ACM, New York (2014)
15. Jerald, J.: Scene-motion- and latency-perception thresholds for head-mounted displays (2009)
16. Weech, S., Kenny, S., Barnett-Cowan, M.: Presence and cybersickness in virtual reality are negatively related: a review. Front. Psychol. 10, 158 (2019). https://www.frontiersin.org/article/10.3389/fpsyg.2019.00158
17. Nesbitt, K., Nalivaiko, E.: Cybersickness. In: Lee, N. (ed.) Encyclopedia of Computer Graphics and Games, pp. 1–6. Springer International Publishing, Cham (2018). https://doi.org/10.1007/978-3-319-08234-9_252-1
18. LaViola, J.J.: A discussion of cybersickness in virtual environments. ACM SIGCHI Bull. **32**(1), 47–56 (2000)
19. Weech, S., Kenny, S., Barnett-Cowan, M.: Presence and cybersickness in virtual reality are negatively related: A review. Front. Psychol. **10**, 158 (2019)
20. Zhang, C.: Investigation on motion sickness in virtual reality environment from the perspective of user experience. In: Proceedings of 2020 IEEE 3rd International Conference on Information Systems and Computer Aided Education, ICISCAE 2020, pp. 393–396 (2020)
21. Chang, E., Kim, H.T., Yoo, B.: Virtual reality sickness: a review of causes and measurements. Int. J. Hum. Comput. Interact. **36**(17), 1–25 (2020)
22. Fulvio, J.M., Ji, M., Rokers, B.: Variations in visual sensitivity predict motion sickness in virtual reality. Entertainment Comput. **38**, 100423 (2021)

23. Jung, J., et al.: A review on interaction techniques in virtual environments. In: Proceedings of the 2014 International Conference on Industrial Engineering and Operations Management, pp. 1582–1590 (2014)
24. Bamodu, O., Ye, X.: Virtual Reality and Virtual Reality System Components. Atlantis Press (2013)
25. Henderson, A., Korner-Bitensky, N., Levin, M.: Virtual reality in stroke rehabilitation: a systematic review of its effectiveness for upper limb motor recovery. Top. Stroke Rehabil. **14**(2), 52–61 (2007)
26. Mahmud, N. I. M. M., et al. (2019). Learning performance assessment using mobile-based augmented reality application for preschool environment. Int. J. Recent Technol. Eng. **8**(2Special Issue 3), 436–439 (2019)
27. Tsyktor, V.: What Is Semi-Immersive Virtual Reality? – The Technology Simplified, February 2019. https://cyberpulse.info/what-is-semi-immersive-virtual-reality/