Jurnal Pendidikan Vokasi
Volume 15, No. 1, 2025, pp. 24-44
Online: https://journal.uny.ac.id/index.php/jpv

Cybersickness in virtual reality research: A comprehensive bibliometric review and visualisation

Arif Ainur Rafiq [1] *, Dwi Sudarno Putra [2], Mochamad Bruri Triyono [3], Dian Novian [4]
[1] Politeknik Negeri Cilacap, Indonesia
[2] Universitas Negeri Padang, Indonesia
[3] Universitas Negeri Yogyakarta, Indonesia
[4] Universitas Negeri Gorontalo, Indonesia
* Corresponding Author. Email: aar@pnc.ac.id

ARTICLE INFO

Article History
Received:
13 April 2025;
Revised:
23 September 2025;
Accepted:
15 November 2025;

Keywords
Bibliometric review;
CiteSpace;
Cybersickness;
Virtual reality research;
VOSviewer

ABSTRACT

Cybersickness has emerged as a critical challenge in the widespread adoption of virtual reality (VR) technologies across education, healthcare, gaming, and training contexts. As research on cybersickness continues to expand rapidly, a comprehensive mapping of its intellectual structure and research trends is needed. This study aims to systematically analyze the global development of cybersickness research in virtual reality through a bibliometric approach. A total of 1,027 journal articles indexed in the Scopus database, published between 1995 and 2024, were retrieved and analyzed. Bibliometric and visualization techniques were applied using VOSviewer and CiteSpace to examine publication growth, citation patterns, influential authors, leading journals, institutional and country contributions, keyword co-occurrence networks, and citation burst trends. The results reveal a substantial increase in cybersickness-related publications over the past decade, indicating growing scholarly attention driven by advances in VR technology and its broader application domains. Research output is dominated by the fields of computer science, medicine, engineering, psychology, and social sciences. The analysis identifies Virtual Reality and IEEE Transactions on Visualization and Computer Graphics as the most productive journals, while authors such as Stephen Palmisano and Behrang Keshavarz emerge as key contributors. Keyword co-occurrence and timeline analyses highlight evolving research themes, including motion sickness, user experience, head-mounted displays, cognition, and VR exposure. Citation burst detection further indicates a recent shift toward user-centered design and mitigation strategies. Overall, this bibliometric review provides a comprehensive overview of the knowledge structure, research hotspots, and emerging trends in cybersickness research. The findings offer valuable insights for researchers, VR developers, and educators, and serve as a foundation for future interdisciplinary studies aimed at improving user comfort and optimizing VR-based applications.

INTRODUCTION

The potential applications of virtual reality (VR) in the classroom have recently become a topic of considerable interest. The benefits of using VR as a pedagogical medium have been extensively studied, and the results demonstrate that it can improve outcomes for both students and teachers. Virtual environments can help students learn and practice skills that are challenging to master through traditional instruction methods (Dalgarno & Lee, 2010; Garzón et al., 2019). However, the impact of VR on the next generation of engineers warrants an in-depth study (Boelt et

al., 2022; Karabulut-Ilgu et al., 2018). A lack of studies examining the interaction between student instructors and industry with respect to learning abilities and predicted learning outcomes. These studies tend to focus on VR and engineering education.

VR is a tool for building simulated worlds using computer-generated imagery and interactive software (Nguyen et al., 2019; X. Yue Qiu et al., 2021; Valdez et al., 2013). This innovation may make the surroundings look and feel like our own or create fantasy worlds in which people can have adventures that would be inconceivable in everyday reality. Virtual reality headsets or multi-projector setups replicate three-dimensional settings with relatively lifelike visual and aural feedback. Virtual reality first appeared as a concept in the 1960s, and it is characterized by using sensory simulators that can offer the illusion of realism by stimulating the human senses of sight, sound, smell, and touch through the presentation of moving 3D visuals (Flavián et al., 2021; Serrano et al., 2016).

Over the past few decades, VR has played several pivotal roles in the entertainment sector. However, studies conducted since the 1980s have examined whether VR is useful for teaching (Auld & Pantelidis, 1994; Pantelidis, 2010). The availability of VR technology paves the way for a novel approach to education, which can supplement more conventional techniques. Virtual reality and educational technology can enable novel instructional techniques that supplement more conventional approaches. With this novel method, students' interest in learning is piqued in a manner distinct from that prompted by sensory knowledge engagement (Harris et al., 2019). Virtual reality aids education by providing a more realistic simulation of an action or function being learned. Virtual reality in the classroom is promising because it provides a safe space for students to recognize and investigate abstract or complex information (Bourhim & Cherkaoui, 2020; Morélot et al., 2021). As a field of study, VR encompasses many aims, from improving teaching efficiency to creating educational content across disciplines. The effects can have far-reaching implications for academic goals (Fowler, 2015; Luo et al., 2021; Mulders et al., 2020).

In line with these intended pedagogical outcomes, researchers have also explored the part VR can play in fostering growth in students' interest in learning, their attitudes towards it, and their ability to handle its mental demands (Chen et al., 2022; Ip & Li, 2022; Makransky et al., 2021; Petersen et al., 2020). New difficulties arise from VR's rapid development, as it will affect study results and necessitate maintaining certain constants when measuring its impact on educational aims (Daniela & Lytras, 2019). Virtual reality is an innovative technology transforming the educational landscape (Portman et al., 2015). By immersing users in realistic, interactive virtual environments, VR provides a unique and engaging medium for teaching and training across disciplines. This introduction provides a comprehensive overview of VR, highlighting its key features, potential benefits, and transformative impact on education.

Additionally, it examines the current state of VR adoption in educational settings and outlines the article's goals. Virtual reality is an advanced technology that simulates a three-dimensional, computer-generated environment that users can explore and interact with via specialized devices. By wearing a Head-Mounted Display (HMD) or using other sensory input devices, users are immersed in a virtual world that can be visually and audibly responsive to their movements and actions (Ramaseri Chandra et al., 2022; Tian et al., 2022). The virtual environment can replicate real-world settings or create imaginary realms, offering limitless possibilities for experiential learning (Kolb & Kolb, 2005). Virtual reality has garnered significant attention in education due to its potential to enhance learning experiences (Maresky et al., 2019; Pyatt & Sims, 2012; Truchly et al., 2018). By providing an immersive and interactive environment, VR enables learners to engage in hands-on activities (Hu, Au, & Lee, 2017), simulate complex scenarios (Maffei et al., 2016), and manipulate objects or data, thereby promoting active participation and experiential learning (Truchly et al., 2018). This technology can facilitate knowledge retention, improve spatial understanding, enhance critical thinking, and foster collaborative learning among students. Furthermore, VR can accommodate various learning styles and enable personalized learning experiences, catering to the unique needs of individual learners (Okechukwu & Udoka, 2011). While VR holds great promise for education, its widespread adoption is still early (Elmqaddem, 2019). The cost of VR hardware and software, technical requirements, and the need for specialized training and support have posed barriers to implementation in educational institutions. However, advancements

in VR technology and the growing availability of affordable VR devices are gradually expanding access to this transformative tool (Grassini & Laumann, 2020; Häfner et al., 2013). Educators, researchers, and developers are actively exploring ways to integrate VR into curricula, develop educational content, and evaluate its impact on learning outcomes.

Virtual reality technology has revolutionized education by providing immersive, interactive learning experiences. By simulating realistic environments, VR enables learners to engage in hands-on activities and explore complex concepts, enhancing their understanding and retention. However, the adoption of VR in educational settings has been accompanied by a significant challenge: cybersickness. It is also known as VR sickness or VR-induced motion sickness and refers to symptoms such as nausea, dizziness, headaches, and eye strain associated with VR use. These symptoms arise from a perceptual mismatch between the virtual environment's visual stimuli and the user's physical movements, resulting in a sensory conflict. As a result, cybersickness can hinder the learning process and adversely affect the overall user experience. The prevalence and impact of cybersickness in VR-based learning environments have attracted the attention of researchers and educators. Recent studies have indicated that a considerable portion of users, ranging from 20% to 80%, experience cybersickness symptoms during VR experiences designed for educational purposes. This issue not only hampers the effectiveness of VR as a learning tool but also raises concerns regarding user acceptance and the potential long-term consequences of prolonged exposure to cybersickness.

Understanding the underlying causes and mechanisms of cybersickness is essential to address this problem effectively. Several factors contribute to cybersickness, including discrepancies between visual and vestibular stimuli, head-tracking latency, field-of-view limitations, and system latency. In addition, individual differences in susceptibility to cybersickness have been observed, with factors such as age, gender, and prior experience with VR impacting the likelihood and severity of symptoms. Mitigating cybersickness in VR for Learning is crucial for maximizing the educational benefits of this technology. Researchers have explored various strategies to alleviate cybersickness symptoms, including optimizing visual display parameters, reducing latency, implementing effective locomotion techniques, and gradually acclimating users to VR environments.

Additionally, the use of alternative sensory stimuli, such as haptic feedback, has shown promise in reducing cybersickness and enhancing user comfort. Research on cybersickness in VR for Learning has made significant strides, but challenges remain in fully understanding its implications and developing practical mitigation approaches. Studies have highlighted the need for standardized measurement techniques, comprehensive user studies, and the integration of user feedback to enhance the design and implementation of VR systems for educational purposes.

This article aims to provide a comprehensive overview of the challenges and implications of cybersickness in VR-based learning environments. It will delve into recent research findings, exploring the causes and contributing factors of cybersickness, discussing its impact on learning, and examining current mitigation strategies. By addressing these aspects, this article aims to contribute to the ongoing efforts to leverage VR technology for educational purposes while ensuring a comfortable and immersive learning experience.

LITERATURE REVIEW

Cybersickness, also called VR sickness or VR-induced motion sickness, is a phenomenon characterized by discomfort and symptoms like motion sickness (Baldoni et al., 2023; Bockelman & Lingum, 2017; Chang et al., 2020; Rebenitsch & Owen, 2016). It arises from a sensory conflict between the visual cues in the virtual environment and the user's physical motion or expectations (Gallagher & Ferrè, 2018). The prevalence of cybersickness varies across studies, with reported incidence rates ranging from 20% to 80% depending on factors such as VR system characteristics, user susceptibility, and task complexity (Beer & Mulder, 2020; Thisgaard & Makransky, 2017). A range of factors contribute to the occurrence and severity of cybersickness. Visual-vestibular conflict, caused by inconsistencies between visual stimuli and the user's vestibular (balance) system, is a primary cause (Arshad et al., 2021; Krokos et al., 2019). Latency and lag in the VR system, field-of-view limitations, synthetic locomotion methods, and conflicting sensory inputs can also induce

cybersickness. Individual differences, including age, gender, previous VR experience, and susceptibility to motion sickness, will influence the severity of cybersickness symptoms.

Cybersickness poses challenges to the educational effectiveness of VR experiences. Studies have shown that cybersickness can negatively impact learning outcomes, user engagement, and satisfaction. The symptoms of cybersickness, such as nausea and dizziness, may hinder cognitive processes, attention, and information retention during VR-based learning tasks. Moreover, the discomfort associated with cybersickness can lead to a reluctance to engage with VR technology and limit the overall acceptance and adoption of VR in educational settings. Researchers have explored various approaches to mitigate cybersickness in VR for learning. These include optimizing visual display parameters (e.g., reducing latency, increasing frame rate), employing comfortable locomotion techniques (e.g., teleportation, redirected walking), and designing user-adaptive systems that account for individual differences in susceptibility to cybersickness. Gradual exposure to VR, providing breaks during sessions, and incorporating multimodal feedback (e.g., haptic feedback) have also shown promise in reducing cybersickness symptoms (S. Chan, 2020; Harris et al., 2019).

Accurate measurement and evaluation of cybersickness are essential for reliable research findings and effective mitigation strategies (Arshad et al., 2021; Valdez et al., 2013). Researchers have employed self-report questionnaires, physiological measures (e.g., heart rate variability), and behavioural observations to assess cybersickness symptoms (Arshad et al., 2021; Caserman et al., 2021; Cassani et al., 2020; Chang et al., 2020). The development of standardized assessment tools and objective metrics for quantifying cybersickness is an ongoing area of research that facilitates better comparisons across studies and aids in designing more user-friendly VR systems. Cybersickness remains a significant challenge in VR-based learning, affecting the overall user experience and potentially hindering educational outcomes (Freina & Ott, 2015; Graeske & Sjöberg, 2021). This literature review provides a comprehensive overview of current knowledge on cybersickness in VR for learning, including its definition, prevalence, causes, effects, and mitigation strategies. The findings emphasize the importance of optimizing VR system design, accounting for individual differences, and employing effective mitigation strategies to minimize cybersickness and enhance the educational potential of VR technology. Future research should focus on standardized measurement techniques, longitudinal studies, and the development of user-centric guidelines to promote comfortable and practical VR-based learning experiences.

METHOD

VOSviewer is used for bibliometric analysis (Ariyani et al., 2022; Masduki et al., 2022; Muhammad et al., 2022; Qin et al., 2022; Suprapto et al., 2021). The data are obtained for the graphical representation of figures and tables. According to the results of some previous literature research, the most relevant literature indicators of this work are: (1) The type of document; (2) The author; (3) The institution; (4) The country; (5) The cited document; (6) The source of the journal; and (7) The keywords of the authors that often occur together (Christ-Ribeiro et al., 2021; Rodríguez-Rojas et al., 2021; Zyoud & Zyoud, 2021). By importing exported Excel data and considering phrases from index keywords, VOSviewer can generate a network of occurrence terms. Identifying multidisciplinary methods and research directions is linked to the co-occurrence of phenomena. (Christ-ribeiro et al., 2021; Gall et al., 2007; Guo et al., 2019; Lulewicz-Sas, 2017; Nassaji, 2015; Zyoud & Zyoud, 2021). The following programs were utilized to visualize the data: VOSviewer, Microsoft Excel, and CiteSpace.

Bibliometric analysis has existed since the early 20th century (Sakata et al., 2013; Zhang et al., 2021; Zhou et al., 2021). The term "bibliometrics" refers to a statistical method for compiling information on the authors, institutions, journals, and other relevant sources of publications (de Melo et al., 2022). Due to the growing body of literature on a specific subject, it is helpful to employ a variety of quantitative rubrics to assess the most critical developments in that field (Marvuglia et al., 2020). A replicable review procedure open to public scrutiny ensures that the results of this analysis are reliable. By relying on objective evaluations derived from computer programming, the inherent risk of conducting a subjective literature review is minimized (Bretas & Alon, 2021). Bibliometric research is not constrained by time or sample size (Yu et al., 2020). In a recent study, well-known

pieces of bibliometric software such as VOS-viewer (Waltman et al., 2010), Bibliometrics (Aria & Cuccurullo, 2017), Hist-Cite (Bornmann & Marx, 2012; Garfield et al., 2006; Lucio-Arias & Leydesdorff, 2008), CiteSpace (Chen, 2006; Chen et al., 2010), CiteNetExplorer (van Eck & Waltman, 2014), SciMAT (Cobo et al., 2012), and others have been utilized.

The applications of bibliometric analysis are widespread in various fields, including food science and technology (Christ-Ribeiro et al., 2021; Musa et al., 2021; Yeung et al., 2018), engineering (Hincapie et al., 2021; Huang & Xin, 2020), computer science (Zyoud & Zyoud, 2021), medical (Alsaman et al., 2021; Santisteban-Espejo et al., 2020), education (Goksu, 2021), economics (Donthu et al., 2021; Saleem et al., 2021), and social science (Palácios et al., 2021). This analysis highlights the transformation of research topics, challenges, and emerging trends (Flórez-Martínez et al., 2022). Hence, we need the information offered by this analysis to understand publication trends and potential applications.

Data Gathering

We retrieved scientific papers published from 1991 to 2024 by performing a subject search in the Scopus database. Scopus is widely regarded as the most extensive citation database and repository of abstracts for peer-reviewed literature. Our study used Scopus as a bibliometric database because it has a broader scope than Web of Science and PubMed (Christ-Ribeiro et al., 2021; Falagas et al., 2008; Mongeon & Paul-Hus, 2016). Previous bibliometric studies relied on data extracted from the Scopus database for analysis. The data extracted from Scopus, including bibliographic metadata, keyword combinations, and cited references, provided valuable information.

The data was retrieved for examination on April 11, 2024. A thorough investigation was conducted to mitigate potential bias arising from daily database updates, which could introduce minor alterations over time. The purpose was to expedite the completion of the search within a day (Ellegaard & Wallin, 2015; Musa et al., 2021). The search phrases "{("cybersickness" OR "VR sickness" OR "VR-induced motion sickness" OR "motion sickness" OR "simulator sickness" OR "cyber side effects") AND "virtual reality"}" were utilized to locate publications in the published literature. The database produced 2.309 articles, as shown in the flowchart of the research methodology (Figure 2).

Subsequently, a filtration process is executed. Filters are crucial when searching for articles in the Scopus database, as they enable users to refine search results based on specific criteria. The purpose of this filter feature is to reduce the number of articles displayed, thereby facilitating the discovery of material pertinent to the study requirements. The search phrase was changed to "{("cybersickness" OR "VR sickness" OR "VR-induced motion sickness" OR "motion sickness" OR "simulator sickness" OR "cyber side effects") AND "virtual reality") AND PUBYEAR > 1995 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (LANGUAGE, "English")). One thousand twenty-seven publications were found to be connected to the process in this bibliometric.

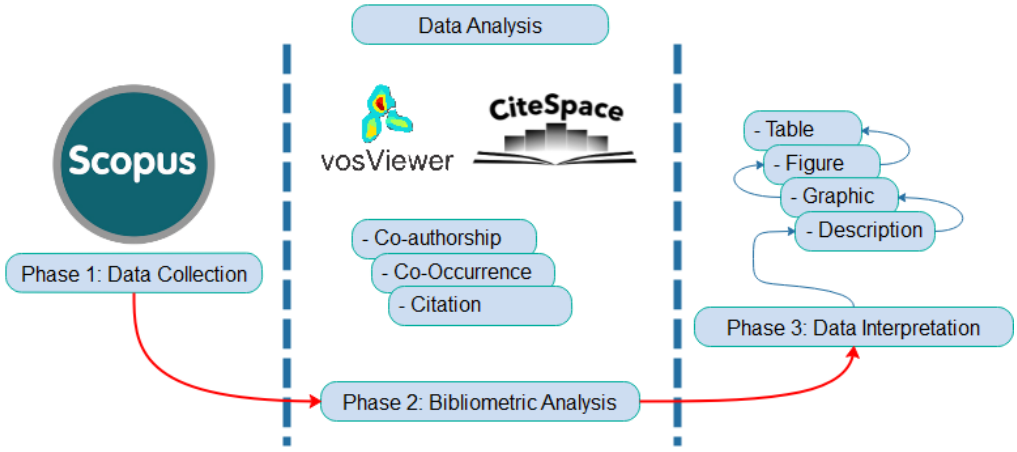

Figure 1. Bringing Up Style in the Journal Template

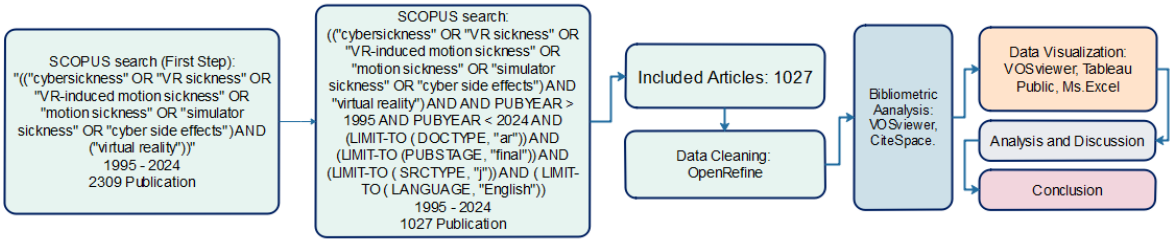

Figure 2, Overview of Research Methodology

Data Clean-up

The first dataset contains redundant information. Initially, the OpenRefine software was used to eliminate duplicate data. It is a cost-free, open-source desktop application for data cleansing and modification (Groves, 2016; Tillman, 2016). We transformed plural and singular nouns into their respective forms by categorizing them as singular or plural. Consolidating vocabulary into a unified lexicon also encompassed observations that conveyed the same meanings (Heikkinen & Marko, 2019). Multiple obligatory manual inspections and assessments were conducted to guarantee the appropriate cleaning procedure. Subsequently, the data underwent manual cleansing using a thesaurus file supplied by VOSviewer.

RESULTS AND DISCUSSION

Results

Background Analysis

Preliminary data analysis can elucidate the fundamentals of previously published information. This section presents a discussion of the development of research orientations on cybersickness, publications, and citations. Results are depicted in Figures 3 through 6. The dataset, covering the years 2013 through 2024, comprises 858 entries. Figure 3 shows the change in these parameters over more than a decade of research on cybersickness. A pattern of increasing publications is evident, with the highest counts in 2019 (77), 2020 (130), 2021 (169), 2022 (177), and 2023 (177). The 2024 figure is lower because the Scopus data were collected in April, so the data may still change. Since 2015, the total number of publications has increased gradually. This pattern also implies that the number of publications will continue to increase as VR technology is adopted across disciplines, particularly in education. The increasing number indicates widespread agreement between researchers on the importance of this field, and this trend also shows that the number of publications will decrease.

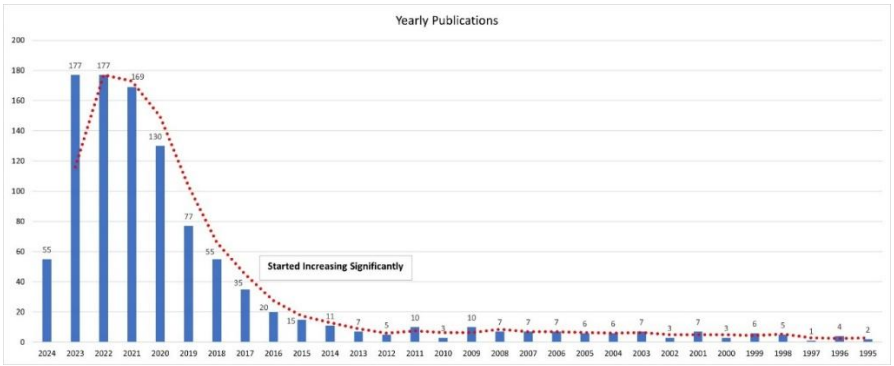

Figure 3. Yearly Trends in Publication on Cybersickness in VR

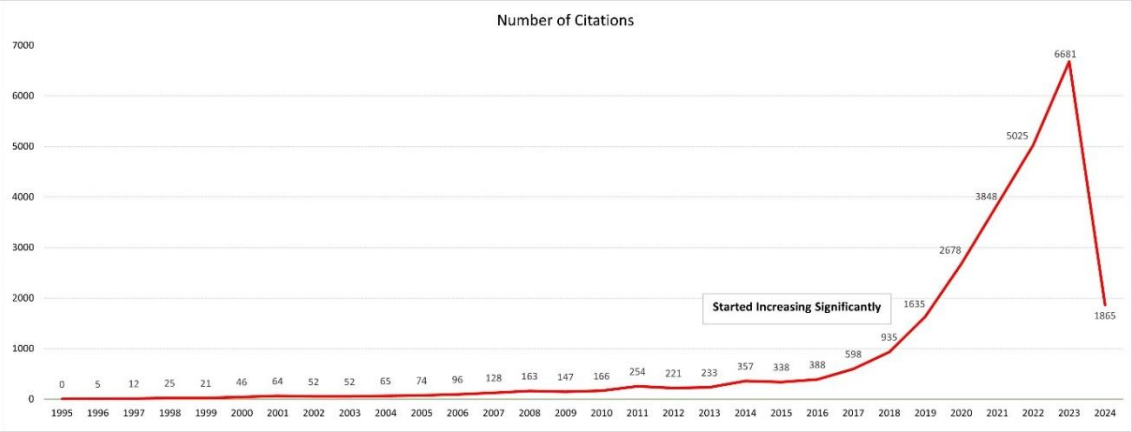

Figure 4. Yearly Citations of Cybersickness in VR Publications

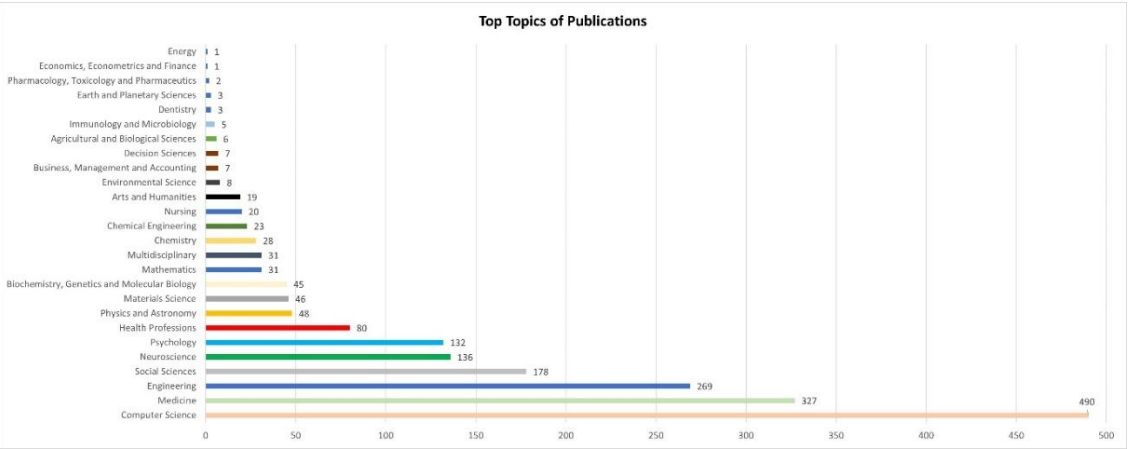

Figure 5. Top Topics in Publications on Cybersickness in VR

Figure 4 shows the increase in citations in 2023 (6681). This increase indicates that researchers have increasingly focused on the impact of cybersickness on VR in recent decades. Significant emphasis has been placed on improving research productivity in environmental innovation and on the citation effect in recent years. Several factors have led to a dramatic increase in research on cybersickness in VR implementation over the last decade. First is the widespread adoption of VR technology. The last decade has seen a significant increase in the availability and affordability of VR technology, leading to its widespread adoption in various industries, including gaming, education, healthcare, and training. With increasing use of VR, there is a greater need to understand and mitigate potential side effects, such as cybersickness. The second is increased awareness.

As VR technology has become more popular, awareness of cybersickness and its effects has increased. It has increased interest among researchers, developers, and users in better understanding. Third, advancements in research tools and techniques, such as eye-tracking technology, physiological monitoring, and simulation software, have enabled researchers to conduct more in-depth studies on cybersickness. These tools allow researchers to gather more accurate data and insights into the phenomenon. Fourth, the focus is on user experience. As VR developers strive to create more immersive and engaging experiences, there is a greater focus on understanding and mitigating factors that can detract from the overall user experience, including cybersickness. Last are health and safety concerns. Cybersickness can negatively affect user health and safety, including discomfort, disorientation, and nausea. As a result, there is a growing interest in understanding how to prevent or minimize cybersickness to ensure a safe and enjoyable VR experience.

A total of 26 distinct study categories were referenced in the papers, and Figure 5 summarises these categories. Among research topics related to cyber addiction, computer science

was the most investigated, accounting for 490 (25.2%) of the total. Medicine (327; 16.8%), engineering (269; 13.8%), social sciences (178; 9.1%), neuroscience (136; 7%), and psychology (132; 6.7%) were among the other areas of study that showed relatively consistent levels of consistency. Although computer science has appeared as the primary focus of the cybersickness domain, other areas are also receiving significant interest and investment, as shown in Figure 5. This is evidenced by the number of documents indexed in the Scopus database.

Citation Analysis

Citation analysis provides valuable insights into how frequently other academic works cite the scholarly work. This information can indicate the work's influence or relevance within the literary community. Citation analysis is essential in bibliometric analysis, including measuring impact, identifying research trends and patterns, recognizing influence and collaboration, identifying relevant literature, and evaluating researcher productivity and quality. By conducting citation analysis, we can assess the impact and relevance of scholarly works in a particular field and inform decision-making in research and scientific development (Cawkell, 1975; J. Qiu et al., 2017).

Table 1 presents a compilation of the 15 most notable authors. Based on the Scopus database used in this bibliometric analysis, 3,973 distinct authors have contributed to research articles on cybersickness. A VOSviewer analysis was conducted to identify the authors with the highest number of publications on environmental innovation. According to the data presented in Table 1, Stephen Palmisano has the most published works, with 17, followed by Behrang Keshavarz, with 15. The following highest-ranking authors are Maximino Bessa and Miguel Melo, with 14. Bernhard Riecke follows with 11 papers, and Juno Kim has nine works. These data indicate that the topic remains in its early stages of development, as few well-known authors and experts across several disciplines are currently contributing. Upon examination of the most highly ranked writers, the number of documents they have produced remains relatively modest, which is considered acceptable for researchers.

Table 1. The rank of the Top 15 Best Authors

Rank	Authors	Doc
1	Stephen Palmisano	17
2	Behrang Keshavarz	15
3	Maximino Bessa	14
4	Miguel Melo	14
5	Bernhard E. Riecke	11
6	Juno Kim	9
7	Thomas A Stoffregen	8
8	Heiko Hecht	8
9	Stéphane Bouchard	7
10	Jinmo Kim	7
11	Simone Gressini	7
12	Michael Barnett-Cowan	7
13	Jelte E. Bos	6
14	José Vasconcelos-raposo	6
15	Jože Guna	6

Table 2 presents a comprehensive list of the 15 Journals that have published the most articles on cybersickness. According to the statistics in Table 2, there are 1,027 documents on this subject, distributed across 157 publications. Table 2 presents the top 10 journals that published the most articles on cybersickness. Significantly, 353 papers, accounting for approximately 35% of the total 1027 articles, were exclusively published in 15 publications.

When ranked by the number of documents, VR ranks first with 71 papers. The journal ranked second to IEEE Transactions on Visualization and Computer Graphics, scoring 44, while Frontiers in Virtual Reality is ranked third with 37. Displays is a prominent publication in display technologies, materials, components, methods, and systems, as well as display-human interaction, visual signal processing and analysis, and visual perception, publishing 30 papers. Thus, this suggests an increase

in studies on cybersickness in display technology. Furthermore, our research corroborates this theory, based on Bradford's Law (1934), which posits that a few journals publish most papers on a given subject. The published literature on environmental innovation suggests that scholars from several disciplines are interested in this subject.

Table 2. The Rank of the Top 15 Journals

Rank	Journal	Doc
1	Virtual Reality	71
2	IEEE Transactions on Visualization and Computer Graphics	44
3	Frontiers in Virtual Reality	37
4	Displays	30
5	Applied Ergonomic	24
6	IEEE Access	21
7	JMIR Serious Games	19
8	Plos One	18
9	Human Factors	14
10	Applied Sciences Switzerland	13
11	Cyberpsychology and Behavior	13
12	Experimental Brain Research	13
13	Journal of Medical Internet Research	13
14	Sensors	12
15	Annual Review of Cybertherapy and Telemedicine	11

Table 3. The Rank of the Top 15 Journals

Rank	Authors	Citation	TLS
1	Behrang Keshavarz	841	19
2	Stephen Palmisano	674	23
3	Hyun Taek Kim	650	6
4	Albert Rizzo	641	10
5	Lisa Rebenitsch	618	3
6	John F. Golding	581	2
7	Charles Owen	580	2
8	Thomas A. Stoffregen	568	13
9	Heiko Hecht	567	12
10	Robert S. Kennedy	536	11
11	Kay M. Stanney	495	8
12	Jaehyun Park	450	12
13	Hyun K. Kim	450	12
14	Mungyeong Choe	444	8
15	Yeongcheol Choi	441	6

Table 3 lists the fifteen authors who have been quoted most frequently. Among the fifteen authors with the highest number of articles, as indicated in Table 1, only Behrang Keshavarz (15 papers; 841 citations; 19 TLS), Palmisano (17 papers, 674 citations; 23 TLS), Kim (4 papers; 650 citations; 6 TLS), Lizzo (4 papers; 641 citations; 10 TLS), and Rebenitsch (4 papers; 618 citations; 3 TLS) are also included in the list of authors with the highest number of citations, as shown in Table 3. This discovery implies that these five authors have writings that are extensively read and have a significant impact. This data also indicates that authors with many documents do not necessarily have a correspondingly high number of citations. Several factors contribute to this phenomenon, including low research quality, limited accessibility, narrow or specialized focus, lack of relevance to current trends or interests, subpar writing and presentation quality, limited professional connections, insufficient promotional efforts, and unfortunate circumstances.

This analysis adds the total link strength (TLS) measurement. In bibliometric analysis, total link strength refers to the sum of the strength of all the connections (links) between nodes (entities such as authors, journals, or keywords) in a bibliometric network. The strength of a link typically represents the frequency or intensity of the interactions between two nodes, such as the number of

co-authored papers between two authors or the number of times a keyword appears in the same paper as another keyword. TLS provides a measure of the overall connectedness or collaboration intensity within a network, which can help understand the structure and dynamics of scholarly communication.

The citation frequency of a publication is occasionally employed to assess its impact on the advancement of scholarly research in a specific field. Moreover, the frequency at which other writers cite a journal can serve as a crucial metric for assessing the effect or influence of a scientific study. A publication's influence within a specific discipline is more likely to be recognized with a greater citation count. The frequency of citations can also indicate a publication's significance and impact on the advancement of knowledge in a specific field. Examining these citation patterns can yield valuable insights regarding trends in research, the evolution of concepts, and the standing and impact of academics or institutions in a specific domain. Worldwide collaborations on cybersickness indicate extensive communication and cooperation among academics, who have produced some of these texts.

Table 4. Top 20 Most-Cited Publications on Cybersickness

Rank	Authors	Journals	Year	Citations
1	Jensen, L., and Konradsen, F.	Education and Information Technologies	2018	697
2	Rebenitsch, L., and Owen, C.	Virtual Reality	2016	526
3	Kim, H.K., Park, J., Choi, Y., and Choe, M.	Applied Ergonomics	2018	441
4	Munafo, J., Diedrick, M., and Stoffregen, T.A.	Experimental Brain Research	2017	363
5	Chang, E., Kim, H.T., and Yoo, B.	International Journal of Human-Computer Interaction	2020	353
6	Keshavarz, B., and Hecht, H.	Human Factors	2011	350
7	Saredakis, D., Szpak, A., Birckhead, B., Rizzo, A., and Loetscher, T.	Frontiers in Human Neuroscience	2020	307
8	Golding, J.F.	Personality and Individual Differences	2006	284
9	Golding, J.F.	Autonomic Neuroscience: Basic and Clinical	2006	273
10	Kim, Y.Y., Kim, H.J., Kim, E.N., Ko, H.D., and Kim, H.T.	Psychophysiology	2005	267
11	Gold, J.I., Kim, S.H., Kant, A.J., Joseph, M.H., and Rizzo, A.	Cyberpsychology and Behavior	2006	248
12	Bos, J.E., Bles, W., and Groen, E.L.	Displays	2008	222
13	Parsons, T.D., Bowerly, T., Buckwalter, J.G., and Rizzo, A.A.	Child Neuropsychology	2007	202
14	Dennison, M.S., Wisti, A.Z., and D'Zmura, M.	Displays	2016	196
15	Moss, J.D., and Muth, E.R.	Human Factors	2011	186

Table 5. The Rank of the Top 10 Institutions Contributing to the Cybersickness Topic

Rank	Countries	Institution	Publications
1	Australia	School of Psychology, University of Wollongong	11
2	South Korea	Department of Software, Catholic University of Pusan	6
3	South Korea	Institute of Behavioral Science in Medicine, Yonsei University College of Medicine	5
4	Slovenia	Faculty of Electrical Engineering, University of Ljubljana	5
5	United States	School of Kinesiology, University of Minnesota	4
6	Canada	Department of Kinesiology, University of Waterloo	4
7	South Korea	Korea Advanced Institute of Science and Technology	4
8	South Korea	Korea Research Institute of Standards and Science	4
9	Portugal	Inesc Tec	4
10	Netherlands	TNO Perceptual and Cognitive Systems	4

The frequency at which a document is cited serves as an indicator of its importance and visibility. Table 5 presents a comprehensive summary of the 10 most frequently cited papers on cybersickness, including details on the author, year of publication, and the publication itself. Jensen and Konradsen's research has amassed the most citations, totalling 697. Following is Rebenitsch and Owen's work, which has received 526 citations. Kim et al.'s research has garnered 441 citations, placing them in third position. Other works have also received citations, but their specific numbers are not provided. Academics engage in extensive communication and collaboration, as demonstrated by several documents from worldwide cooperation in cybersickness.

Authors Affiliation

The author's affiliations concerning cybersickness are presented in Table 5. The data were analyzed using VOSviewer to extract each author's notes and references and to arrange the author organizations in descending order. VOSviewer is used for its ability to provide extensive data visualization. Scopus reports that 2,710 institutions have conducted research and published papers about cybersickness. Table 5 presents the 15 publishers that produce the most cybersickness content. The School of Psychology at the University of Wollongong in Australia ranked first with 11 publications. It was followed by the Department of Software at the Catholic University of Pusan in South Korea, which had six publications. The Institute of Behavioural Science in Medicine at Yonsei University College of Medicine in South Korea ranked third, with five publications.

According to the data provided, these organizations generally lack documentation. This statistic indicates that research organizations worldwide have not thoroughly investigated numerous aspects of cybersickness. Therefore, our bibliometric findings can inform the development of effective strategies to increase publication output on cybersickness. An institutional contribution is a significant factor in advancing research on cybersickness. The results of these bibliometric analyses highlight the importance of institutional support in promoting implementation research to assess the effects of cybersickness, as corroborated by prior bibliometric studies.

Authors Affiliation

The author's affiliations concerning cybersickness are presented in Table 5. The data were analyzed using VOSviewer to extract each author's notes and references and to arrange the author organizations in descending order. VOSviewer is used for its ability to provide extensive data visualization. Scopus reports that 2,710 institutions have conducted research and published papers about cybersickness. Table 5 presents the 15 publishers that produce the most cybersickness content. The School of Psychology at the University of Wollongong in Australia ranked first with 11 publications. It was followed by the Department of Software at the Catholic University of Pusan in South Korea, which had six publications. The Institute of Behavioural Science in Medicine at Yonsei University College of Medicine in South Korea ranked third, with five publications.

According to the data provided, these organizations generally lack documentation. This statistic indicates that research organizations worldwide have not thoroughly investigated numerous aspects of cybersickness. Therefore, our bibliometric findings can inform the development of effective strategies to increase publication output on cybersickness. An institutional contribution is a significant factor in advancing research on cybersickness. The results of these bibliometric analyses highlight the importance of institutional support in promoting implementation research to assess the effects of cybersickness, as corroborated by prior bibliometric studies.

Burst Detection Analysis

The purpose of conducting burst detection analyses of authors, sources, countries, and institutions in bibliometric analyses is to uncover noteworthy and emerging trends, patterns, and effects within a specific research field. Detecting bursts in author activity helps highlight scholars who make significant contributions or gain recognition within a particular field of study. Additionally, it might aid in monitoring the progress of novel concepts or approaches within the discipline.

Identifying bursts in sources (e.g., journals) may reveal newly emerging or highly significant publications within a specific topic. This information is essential for researchers seeking to publish

their work in esteemed or popular venues. Examining bursts in research output across nations may reveal shifts in global research patterns and identify countries rapidly increasing their research contributions in specific domains. Institutions can utilize burst detection to discover research-intensive institutions and monitor their impact and influence within a specific field over time. Additionally, it can emphasize and showcase the cooperative efforts and alliances formed between different organizations. In summary, burst detection analyses provide academics with significant insights into the dynamics of scholarly communication, enabling them to remain informed about current trends, identify potential collaborators, and make well-informed decisions about their research methods.

Table 6. Top 10 Authors with the Most Potent Citation Bursts from 2003 to 2023

Cited Authors	Year	Strength	Begin	End	2003 - 2023
Graybiel A	2003	7.11	2003	2011	
Reason JT	2003	6.19	2003	2006	
Dichgans J	2004	7.25	2004	2014	
Hettinger LJ	2006	9.68	2006	2019	
Flanagan MB	2011	10.94	2011	2019	
Stoffregen TA	2004	7.74	2017	2018	
Lackner JR	2019	6.76	2019	2020	
Smart LJ	2019	6.08	2019	2021	
Ling Y	2020	6.04	2020	2021	
Prothero JD	2020	6.04	2020	2021	

Table 7. Top 10 Authors with the Most Potent Citation Bursts from 2003 to 2023

Cited Journals	Year	Strength	Begin	End	2003 - 2023
AVIAT SPACE ENVIRON MED	2003	8.1	2003	2017	
INT J AVIAT PSYCHOL	2003	6.19	2003	2017	
INTERNATIONAL JOURNAL OF AVIATION PSYCHOLOGY	2003	6.11	2003	2008	
HUMAN FACTORS	2003	4.75	2003	2008	
APPLIED ERGONOMICS	2003	4.23	2003	2011	
MOTION SICKNESS	2004	14.04	2004	2018	
ERGONOMICS	2005	6.7	2005	2015	
PRESENCE: TELEOPERATORS AND VIRTUAL ENVIRONMENTS	2007	4.13	2007	2020	
PERCEPTION	2008	5.69	2008	2014	
SCIENCE	2019	5.27	2019	2021	
INT. J. AVIAT. PSYCHOL	2019	4.3	2019	2021	

Table 8. Top Countries/Institutions with the Most Potent Citation Bursts from 2003 to 2023

Countries	Year	Strength	Begin	End	2003 - 2023
United States	2003	8.14	2004	2017	
South Korea	2005	5.51	2017	2018	
United Kingdom	2003	3.4	2003	2009	
Institutions					
Department of Otolaryngology, University of Tokushima School of Medicine	2003	3.45	2003	2013	
Department of Software, Catholic University of Pusan	2017	3.65	2017	2018	

Keywords Analysis

Keyword analysis in bibliometrics examines keywords or terms commonly occurring in scientific articles or literature. This analysis facilitates comprehension of research trends, focal points, and advancements in a specific domain. By examining keywords, researchers can ascertain the study's primary focus and monitor the development and changes in the research framework of a particular field. Keyword analysis is a content analysis method that examines the terms used in a publication to understand the structure of a research topic.

Table 9. The Rank of the Top 15 Most Frequently Used Keywords in the Cybersickness Topic

Rank	Keywords	Frequency
1	Virtual reality	947
2	Human	495
3	Male	350
4	Humans	385
5	Female	347
6	Article	344
7	Motion sickness	337
8	Adult	316
9	Cybersickness	306
10	Controlled study	197
11	Diseases	178
12	Simulator sickness	177
13	Questionnaire	143
14	Clinical article	126
15	Helmet mounted display	120

The concepts underlying the words can be inferred from their frequency in the document. This approach enables researchers to identify co-occurrence connections in document content for structural purposes. Visualization techniques simplify the comprehension of intricate relationships within a network. The decision to use VOSviewer for this investigation was based on its exceptional ability to present high-quality diagrams.

In bibliometric analysis, co-occurrence analysis aims to identify relationships between terms (such as keywords, topics, or concepts) based on their co-occurrence in the same documents, titles, abstracts, or other text elements within a dataset. This analysis helps researchers uncover patterns, trends, and connections within a body of literature, providing valuable insights into the structure and content of research fields. Specifically, co-occurrence analysis aims to identify critical topics, discover emerging trends, map the intellectual structure, and facilitate knowledge organization.

An analysis of keyword co-occurrence can provide insights into a particular field's research focus and overall subject matter. Thus, using our collected keyword dataset, we employed VOSviewer to visualize keyword co-occurrence. After identifying 6412 keywords (including author and additional keywords), a criterion of at least five occurrences was used to select the terms displayed in the visualization map.

Table 10. The Rank of the Top 15 Most Frequently Used Keywords in The Cybersickness Topic

Cluster	Top Keywords
Red	Virtual Reality; Cybersickness; Simulator Sickness; Diseases; Immersion
Green	Human; Female; Article; Simulator Sickness Questionnaire; Psychology
Blue	Humans; Male; Adult; Video Games; User Computer Interface
Yellow	Middle Aged; Software; Cognition; Exercise; Rehabilitation
Purple	Simulation; Comparative Study; Education; Training; Teaching

Table 10 displays a comprehensive count of 624 keywords deemed to surpass the minimum threshold and subsequently categorized into nine distinct groups using colour coding. There were 947 instances of VR, 495 cases of humans, 350 instances of males, 385 cases of humans, 347

instances of females, 344 instances of articles, and 344 instances of motion sickness. Meanwhile, the term "cybersickness" was mentioned 306 times. This discovery demonstrates that these keywords are at the forefront of the most captivating domains within cybersickness.

Following the identification of keywords across several clusters, the most prevalent keywords in each cluster are evident. Clustering is a technique used in co-occurrence analysis that seeks to group related phrases, themes, or concepts based on co-occurrence patterns. The fundamental objective of clustering is to organize material in a meaningful manner and to illuminate the underlying structure and relationships within a body of literature. Table 9 displays the keywords most frequently used by the five groupings.

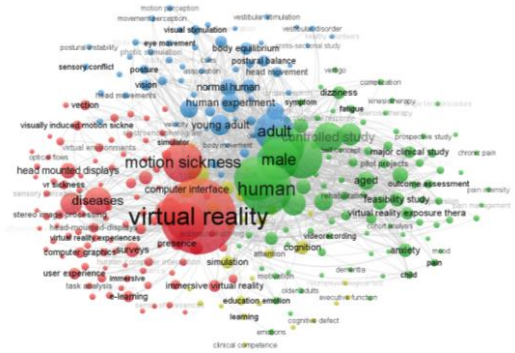

Figure 6. Network Visualization of Keywords

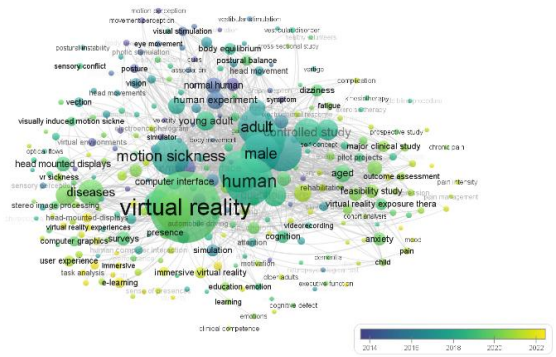

Figure 7. Overlay Visualization of Keywords

Figures 6 and 7 depict the network of co-occurring keywords, showing how keywords are distributed over time across classes. The hue of the keyword's visualization corresponds to the year of publishing. Dark hues indicate earlier publication dates, whereas lighter shades indicate more recent publication dates. The saturation range is determined by the average publication year of a keyword. The overlay visualization indicates that research directions span 2014-2022, with most articles focusing on 2020 and later. This outcome is observable in the resultant annual publications. Based on the visualization, it is evident that there is extensive research on novelty features towards the end of the specified year range.

The CiteSpace program includes a burst-detection capability that enables users to observe the temporal progression of studies on cybersickness. It has come to our attention that the issue of cybersickness has been gaining popularity and growing in prevalence over the years. Upon examination, no notable increase in keyword citations was observed before 2003. Therefore, we focused on the burst detection analysis from 2003 to 2023. Subsequently, we identified the most prominent and well-regarded terms within that timeframe (Table 10).

Table 11 shows the most prominent and well-regarded terms within that specific timeframe. The CiteSpace program includes a burst-detection capability that enables users to observe the temporal progression of studies on cybersickness. It has come to our attention that the issue of cybersickness has been gaining popularity and growing in prevalence over the years. Upon examination, no notable increase in keyword citations was observed before 2003. Therefore, we focused on the burst detection analysis from 2003 to 2023.

The keyword "user computer interface" has a burst strength of 15.99 and was first observed in 2003 and last observed in 2017. By 2003, the terms "article," "computer simulation," "controlled study," and "adult" emerged on the list and rapidly gained recognition as influential keywords in published articles. We discovered that most keywords identified in the burst detection study did not recur entirely but only within specific periods. Between 2017 and 2023, several significant terms emerged, including psychology, video games, user experience, head-mounted display, VR exposure treatment, self-reporting, and cognition. Researchers have begun exploring new problems associated with cybersickness, indicating a development in this field.

Table 11. The Keywords with the Most Potent Citation Bursts in Cybersickness

Keywords	Year	Strength	Begin	End	2003 - 2023
user computer interface	2003	15.99	2003	2017	
article	2003	8.16	2003	2014	
computer simulation	2003	7.87	2003	2016	
controlled study	2003	5.09	2003	2010	
adult	2003	4.1	2003	2010	
pathophysiology	2011	9.54	2011	2019	
simulator sickness	2004	5.28	2011	2014	
vision	2013	7.8	2013	2019	
young adult	2014	12.76	2014	2018	
physiology	2011	13.2	2015	2019	
computer interface	2007	8.59	2015	2018	
procedures	2015	7.41	2015	2018	
photostimulation	2015	4.32	2015	2018	
photic stimulation	2015	4.32	2015	2018	
priority journal	2005	6.87	2016	2020	
postural balance	2017	4.38	2017	2018	
video game	2018	5.94	2018	2021	
psychology	2018	5.18	2018	2020	
video games	2018	4.57	2018	2021	
user experience	2019	9.27	2019	2021	
head-mounted display	2019	5.89	2019	2021	
head-mounted displays	2016	4.53	2019	2020	
virtual reality exposure therapy	2018	5.13	2021	2023	
self-report	2021	4.81	2021	2023	
cognition	2007	4.4	2021	2023	

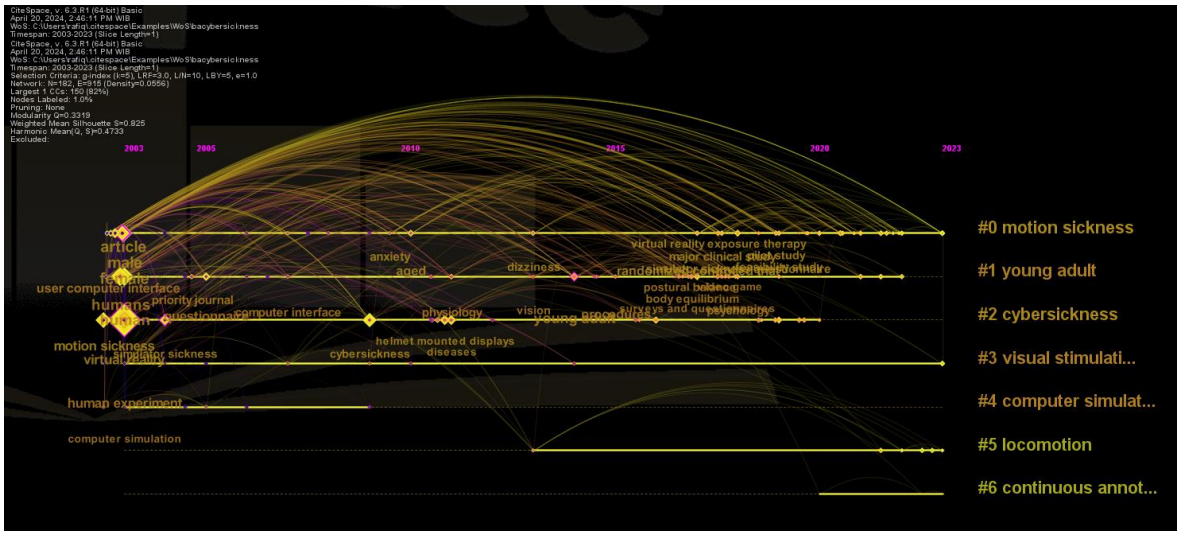

Figure 8. Timeline visualization of keywords from 2003 to 2023

Timeline Visualisation

Timeline visualization analysis in CiteSpace is conducted using bibliometric analysis to observe the development and evolution of a research topic or discipline over time. The main goal is to understand trends, changes, and momentum in the development of scientific literature on a specific topic or discipline. Researchers can identify significant periods in the development of a topic or discipline by examining the timeline. Moreover, it enables tracking of research trends over time, helping researchers understand how research focus has changed and how specific topics have become

popular. In addition, timeline visualization can identify turning points in the development of a topic or discipline. These turning points can be important discoveries.

In published articles, the use of keywords may reflect the progression of a research field. To trace research on cybersickness, we used CiteSpace to analyze a chronology of keyword usage from 2003 to 2023. Identifying emergent patterns of term usage is another application that may be made of this data. The timeline depicted in Figure 8 comprises six distinct clusters of phrases. Timeline keyword clusters are arranged in a hierarchy according to the frequency with which their respective terms appear in the timeline. The connection curves in the figure represent the mutually beneficial relationships among the keywords.

Cluster #0, "motion sickness," contains papers from approximately 2003 to 2023 in Figure 8. With increasing research on cybersickness in VR, the term "motion sickness" has become widely accepted. The study of young adults has been a prominent and popular research focus for a significant period, as seen by the continued presence of cluster #1. Cluster #4 had the shortest duration, concluding in 2009. Cybersickness research is mainly focused on Clusters #0, #2, #3, and #4, and this trend is predicted to continue.

Discussion

Cybersickness is a crucial field of research and practice that involves developing and implementing new technologies, strategies, and processes to address the challenges of VR and promote sustainability. This bibliographic review examines key findings and trends in the literature on cybersickness from 1995 to 2024. Using VOSviewer and CiteSpace, we summarize empirical studies indexed in Scopus and provide a comprehensive overview of the subject's evolution and impact on VR.

We successfully identified research trends, leading authors, institutions, and significant international collaborations in this field by utilizing advanced data visualization tools. This bibliometric analysis offers in-depth insights into the development and future direction of cybersickness research in VR. Temporal analysis reveals that interest in cybersickness research in VR has significantly increased over the past decade. This can be attributed to advancements in VR technology, which have made VR devices more accessible and widely used for entertainment, education, and professional purposes. Early studies primarily focused on identifying and measuring cybersickness symptoms, whereas more recent research has explored symptom mitigation and the enhancement of the user experience.

The study results show that the number of publications has increased steadily, indicating a growing academic focus on cybersickness associated with VR. Researchers are keenly interested in enhancing the productivity and impact of research on cybersickness, underscoring the growing importance of addressing these challenges through innovative approaches. These results are consistent with the findings of Abdullah and Khan (2021), Chan et al. (2021), Yu et al. (2020), and Zhang et al. (2020), who observed a similar trend in the past five years, observing an increasing trend in interest and publication in the field of cybersickness. Additionally, numerous studies have confirmed that these papers constitute the majority of research publications in this field.

Additionally, research on cybersickness is multidisciplinary, attracting researchers from various disciplines. Adopting an interdisciplinary approach highlights the complexity of the challenges and emphasizes the need for collaborative efforts to solve them effectively. A related study Jensen and Konradsen (2018) examined green innovations and found that scholars across management, economics, engineering, and education are actively studying this topic. It reflects the high interest in cybersickness in the current research landscape, as evidenced by the proliferation of research fields and documentation sources. Consistent with other innovation studies (Keshavarz et al., 2015; Palmisano et al., 2020; Rebenitsch & Owen, 2016), the top publications in this study align with the dominant trends. Moreover, various empirical studies have examined the geographical and institutional distribution of research on cybersickness, identifying key countries and institutions actively involved in this field. These studies have consistently recognized the United States, South Korea, and the United Kingdom. These findings are consistent with those of the current study.

Furthermore, the increasing number of papers by Asian academics, particularly from South Korea, indicates a promising trend toward greater interest and the emergence of significant contributions to this research. In recent years, the exponential increase in scientific publications has transcended geographical boundaries and spread to several countries, further supporting this. Despite considerable progress, research on cybersickness in VR still faces several challenges. One of the primary challenges is the individual variability in responses to VR, which makes it difficult to develop universal solutions. The lack of standardization in the measurement and reporting of cybersickness symptoms also hinders the comparison of results across studies. However, the opportunities for future research are substantial. With advances in sensor technology and data analytics, there is potential to develop more precise methods for detecting and mitigating cybersickness. Furthermore, interdisciplinary research combining psychology, computer science, and human-computer interaction design can yield more holistic and practical solutions.

The findings of this review have several practical implications. Understanding the factors that contribute to cybersickness among VR device and application developers can inform the design of more user-friendly products. For researchers, these findings can serve as a basis for more focused and directed future studies. For educators and healthcare professionals, a better understanding of cybersickness can inform the design of more effective interventions for VR users.

Although this study provides promising findings, it has several limitations that should be considered. This bibliometric analysis is limited to publications indexed in Scopus. Consequently, relevant studies published in other databases or non-indexed sources might be excluded, potentially affecting the comprehensiveness of our review. The analysis covers a defined period up to the first quarter of 2024. Significant developments or publications occurring after this period are not included, which may affect the relevance of the findings in rapidly evolving fields such as VR and cybersickness. Bibliometric analysis provides quantitative information on publication trends, citation patterns, and collaborative networks. It does not capture qualitative aspects such as depth of research, methodological rigour, or theoretical advances in cybersickness and VR.

Future bibliometric reviews should consider incorporating additional databases, including Web of Science, Google Scholar, PubMed, and specialized VR research repositories. It would provide a more comprehensive view of the research landscape and include a broader range of publications. Conducting longitudinal bibliometric studies that extend beyond the current cutoff period can capture the field's dynamic nature and identify emerging trends and shifts in research focus over time. Complementing quantitative bibliometric analysis with qualitative reviews of critical publications can provide deeper insights into the content, methodologies, and theoretical contributions. This mixed-methods approach can offer a more nuanced understanding of the research landscape. Future research should explore the impact of emerging technologies, such as AI-driven VR systems and advanced motion tracking, on cybersickness. Understanding how these advancements mitigate or exacerbate cybersickness can guide the development of more user-friendly VR systems. Encouraging interdisciplinary research integrating insights from neuroscience, psychology, computer science, and human-computer interaction can foster a holistic understanding of cybersickness. Collaborative efforts across disciplines can lead to innovative solutions and new research avenues.

CONCLUSION

This article provides comprehensive insights and expertise on recent research advances in cybersickness associated with VR technology. This study examined publications in the Scopus database from 1995 to 2024, using VOSviewer and CiteSpace for analysis. A total of 1,027 relevant papers were collected for analysis using bibliometric methods in this study. Based on this figure, there has been a notable surge in the number of academics and diverse groups interested in studying cybersickness. Based on the comprehensive bibliometric analysis, the publication with the highest number of citations focuses on VR in computer science. The dual-map overlay reveals that most publications by scholars are in computer science, medicine, engineering, social science, neurology, and psychology, in that order. Stephen Palmisano is the most prominent author on cybersickness, having authored 17 documents. Behrang Keshavarz follows closely with 15 papers. Behrang

Keshavarz now holds the most citations among authors, with a total of 841 citations. Following closely after is Stephen Palmisano, who has accumulated 574 citations. Both esteemed researchers consistently produce a high volume of research papers and receive many citations from their peers. The Virtual Reality journal contains the most extensive collection of papers on cybersickness, with 71 documents. The IEEE Transactions on Visualization and Computer Graphics includes 44 papers on the same topic. The School of Psychology at the University of Wollongong is renowned for its prolific production of scholarly articles. In addition, South Korea is the most dynamic nation in this domain, indicating that Asia is emerging as a formidable contender in global research on cybersickness. This analysis comprehensively examines the critical elements of the most often utilized terms, specifically VR, human, and male. These keywords represent the findings of the analysis, which uncover the issues that are now popular and evolving within a specific timeframe. Co-occurrence analysis reveals that the three primary keywords are topics or study focuses that attract researchers' attention in the field of cybersickness. Based on a timeline analysis using CiteSpace, it was determined that motion sickness, young adults, cybersickness, visual simulation, computer simulation, locomotion, and continuous annotation remain significant topics in this research area. Numerous areas remain that warrant further investigation to advance research on cyber-sickness.

REFERENCES

Abdullah, A., & Khan, M. N. (2021). Determining mobile payment adoption: A systematic literature search and bibliometric analysis. *Cogent Business & Management, 8*(1). https://doi.org/10.1080/23311975.2021.1893245

Arshad, I., de Mello, P., Ender, M., McEwen, J. D., & Ferré, E. R. (2021). Reducing cybersickness in 360-degree virtual reality. *Multisensory Research*. https://doi.org/10.1163/22134808-bja10066

Auld, L. W. S., & Pantelidis, V. S. (1994). Exploring virtual reality for classroom use: The virtual reality and education lab at East Carolina University. *TechTrends, 39*(1), 29–31. https://doi.org/10.1007/BF02763872

Baldoni, S., Sassi, M. S. H., Carli, M., & Battisti, F. (2023). Definition of guidelines for virtual reality application design based on visual attention. *Multimedia Tools and Applications*. https://doi.org/10.1007/s11042-023-17488-y

Beer, P., & Mulder, R. H. (2020). The effects of technological developments on work and their implications for continuous vocational education and training: A systematic review. *Frontiers in Psychology, 11*, Article 918. https://doi.org/10.3389/fpsyg.2020.00918

Bockelman, P., & Lingum, D. (2017). Factors of cybersickness. In *Communications in Computer and Information Science* (Vol. 714, pp. 3–8). Springer. https://doi.org/10.1007/978-3-319-58753-0_1

Boelt, A. M., Kolmos, A., & Holgaard, J. E. (2022). Literature review of students' perceptions of generic competence development in problem-based learning in engineering education. *European Journal of Engineering Education*. https://doi.org/10.1080/03043797.2022.2074819

Bourhim, E. M., & Cherkaoui, A. (2020). Efficacy of virtual reality for studying people's pre-evacuation behavior under fire. *International Journal of Human–Computer Studies, 142*, 102484. https://doi.org/10.1016/j.ijhcs.2020.102484

Caserman, P., Garcia-Agundez, A., Gámez Zerban, A., & Göbel, S. (2021). Cybersickness in current-generation virtual reality head-mounted displays: Systematic review and outlook. *Virtual Reality, 25*(4), 1153–1170. https://doi.org/10.1007/s10055-021-00513-6

Cassani, R., Moinnereau, M.-A., Ivanescu, L., Rosanne, O., & Falk, T. H. (2020). Neural interface instrumented virtual reality headsets: Toward next-generation immersive applications. *IEEE*

Systems, Man, and Cybernetics Magazine, 6(3), 20–28. https://doi.org/10.1109/MSMC.2019.2953627

Cawkell, A. E. (1975). Citation analysis. *Nature, 254*(5499), 379–380. https://doi.org/10.1038/254379c0

Chan, P., Van Gerven, T., Dubois, J.-L., & Bernaerts, K. (2021). Virtual chemical laboratories: A systematic literature review of research, technologies and instructional design. *Computers and Education Open, 2*, 100053. https://doi.org/10.1016/j.caeo.2021.100053

Chan, S. (2020). *Identity, pedagogy and technology-enhanced learning: Supporting the processes of becoming a tradesperson*. Springer.

Chang, E., Kim, H. T., & Yoo, B. (2020). Virtual reality sickness: A review of causes and measurements. *International Journal of Human–Computer Interaction, 36*(17), 1658–1682. https://doi.org/10.1080/10447318.2020.1778351

Chandra, A. N. R., El Jamiy, F., & Reza, H. (2022). A systematic survey on cybersickness. *Computers, 11*(4), 51. https://doi.org/10.3390/computers11040051

Chen, B., Wang, Y., & Wang, L. (2022). The effects of virtual reality-assisted language learning: A meta-analysis. *Sustainability, 14*(6), 3147. https://doi.org/10.3390/su14063147

Dalgarno, B., & Lee, M. J. W. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology, 41*(1), 10–32. https://doi.org/10.1111/j.1467-8535.2009.01038.x

Daniela, L., & Lytras, M. D. (2019). Editorial: Themed issue on enhanced educational experience in virtual and augmented reality. *Virtual Reality, 23*(4), 325–327. https://doi.org/10.1007/s10055-019-00383-z

Elmqaddem, N. (2019). Augmented reality and virtual reality in education: Myth or reality? *International Journal of Emerging Technologies in Learning, 14*(3), 234–242. https://doi.org/10.3991/ijet.v14i03.9289

Flavián, C., Ibáñez-Sánchez, S., & Orús, C. (2021). The influence of scent on virtual reality experiences: The role of aroma-content congruence. *Journal of Business Research, 123*, 289–301. https://doi.org/10.1016/j.jbusres.2020.09.036

Fowler, C. (2015). Virtual reality and learning: Where is the pedagogy? *British Journal of Educational Technology, 46*(2), 412–422. https://doi.org/10.1111/bjet.12135

Freina, L., & Ott, M. (2015). A literature review on immersive virtual reality in education: State of the art and perspectives. In *Proceedings of ELearning and Software for Education (ELSE)*.

Gallagher, M., & Ferrè, E. R. (2018). Cybersickness: A multisensory integration perspective. *Multisensory Research, 31*(7), 645–674. https://doi.org/10.1163/22134808-20181293

Garzón, J., Pavón, J., & Baldiris, S. (2019). Systematic review and meta-analysis of augmented reality in educational settings. *Virtual Reality, 23*(4), 447–459. https://doi.org/10.1007/s10055-019-00379-9

Graeske, C., & Sjöberg, S. A. (2021). VR-technology in teaching: Opportunities and challenges. *International Education Studies, 14*(8), 76. https://doi.org/10.5539/ies.v14n8p76

Grassini, S., & Laumann, K. (2020). Are modern head-mounted displays sexist? A systematic review on gender differences in HMD-mediated virtual reality. *Frontiers in Psychology, 11*, Article 1604. https://doi.org/10.3389/fpsyg.2020.01604

Häfner, P., Häfner, V., & Ovtcharova, J. (2013). Teaching methodology for virtual reality practical course in engineering education. *Procedia Computer Science, 25*, 251–260. https://doi.org/10.1016/j.procs.2013.11.031

Harris, D. J., Buckingham, G., Wilson, M. R., & Vine, S. J. (2019). Virtually the same? How impaired sensory information in virtual reality may disrupt vision for action. *Experimental Brain Research, 237*(11), 2761–2766. https://doi.org/10.1007/s00221-019-05642-8

Hu Au, E., & Lee, J. J. (2017). Virtual reality in education: A tool for learning in the experience age. *International Journal of Innovation in Education, 4*(4), 215. https://doi.org/10.1504/IJIIE.2017.10012691

Ip, H. H. S., & Li, C. (2022). Defining virtual reality-enabled learning. *International Journal of Innovation and Learning, 31*(1), 1–18. https://doi.org/10.1504/IJIL.2022.10044241

Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies, 23*(4), 1515–1529. https://doi.org/10.1007/s10639-017-9676-0

Karabulut-Ilgu, A., Jaramillo Cherrez, N., & Jahren, C. T. (2018). A systematic review of research on the flipped learning method in engineering education. *British Journal of Educational Technology, 49*(3), 398–411. https://doi.org/10.1111/bjet.12548

Keshavarz, B., Riecke, B. E., Hettinger, L. J., & Campos, J. L. (2015). Vection and visually induced motion sickness: How are they related? *Frontiers in Psychology, 6*, Article 472. https://doi.org/10.3389/fpsyg.2015.00472

Kolb, A. Y., & Kolb, D. A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of Management Learning & Education, 4*(2), 193–212. https://doi.org/10.5465/amle.2005.17268566

Krokos, E., Plaisant, C., & Varshney, A. (2019). Virtual memory palaces: Immersion aids recall. *Virtual Reality, 23*(1), 1–15. https://doi.org/10.1007/s10055-018-0346-3

Luo, H., Li, G., Feng, Q., Yang, Y., & Zuo, M. (2021). Virtual reality in K–12 and higher education: A systematic review of the literature from 2000 to 2019. *Journal of Computer Assisted Learning, 37*(3), 887–901. https://doi.org/10.1111/jcal.12538

Makransky, G., Andreasen, N. K., Baceviciute, S., & Mayer, R. E. (2021). Immersive virtual reality increases liking but not learning. *Journal of Educational Psychology, 113*(4), 719–735. https://doi.org/10.1037/edu0000473

Maresky, H. S., Oikonomou, A., Ali, I., Ditkofsky, N., Pakkal, M., & Ballyk, B. (2019). Virtual reality and cardiac anatomy. *Clinical Anatomy, 32*(2), 238–243. https://doi.org/10.1002/ca.23292

Morélot, S., Garrigou, A., Dedieu, J., & N'Kaoua, B. (2021). Virtual reality for fire safety training. *Computers & Education, 166*, 104145. https://doi.org/10.1016/j.compedu.2021.104145

Mulders, M., Buchner, J., & Kerres, M. (2020). A framework for the use of immersive virtual reality in learning environments. *International Journal of Emerging Technologies in Learning, 15*(24), 208–224. https://doi.org/10.3991/ijet.v15i24.16615

Nguyen, V. T., Hite, R., & Dang, T. (2019). Web-based virtual reality development in classroom. In *Proceedings of the IEEE International Conference on Artificial Intelligence and Virtual Reality* (pp. 11–18). IEEE. https://doi.org/10.1109/AIVR.2018.00010

Okechukwu, M., & Udoka, F. (2011). *Understanding virtual reality technology: Advances and applications*. InTech. https://doi.org/10.5772/15529

Palmisano, S., Allison, R. S., & Kim, J. (2020). Cybersickness in head-mounted displays. *Frontiers in Virtual Reality, 1*, Article 587698. https://doi.org/10.3389/frvir.2020.587698

Pantelidis, V. S. (2010). Reasons to use virtual reality in education and training courses. *Themes in Science and Technology Education, 2*(1–2), 59–70.

Petersen, G. B., Klingenberg, S., Mayer, R. E., & Makransky, G. (2020). The virtual field trip. *British Journal of Educational Technology, 51*(6), 2098–2114. https://doi.org/10.1111/bjet.12991

Portman, M. E., Natapov, A., & Fisher-Gewirtzman, D. (2015). Virtual reality in architecture. *Computers, Environment and Urban Systems, 54*, 376–384. https://doi.org/10.1016/j.compenvurbsys.2015.05.001

Pyatt, K., & Sims, R. (2012). Virtual and physical experimentation in inquiry-based science labs. *Journal of Science Education and Technology, 21*(1), 133–147. https://doi.org/10.1007/s10956-011-9291-6

Qiu, J., Zhao, R., Yang, S., & Dong, K. (2017). *Informetrics*. Springer.

Qiu, X. Y., Chiu, C. K., Zhao, L. L., Sun, C. F., & Chen, S. J. (2021). Trends in VR/AR technology-supporting language learning. *Interactive Learning Environments*. https://doi.org/10.1080/10494820.2021.1874999

Rebenitsch, L., & Owen, C. (2016). Review on cybersickness. *Virtual Reality, 20*(2), 101–125. https://doi.org/10.1007/s10055-016-0285-9

Serrano, B., Baños, R. M., & Botella, C. (2016). Virtual reality and stimulation of touch and smell. *Computers in Human Behavior, 55*, 1–8. https://doi.org/10.1016/j.chb.2015.08.007

Thisgaard, M., & Makransky, G. (2017). Virtual learning simulations in high school. *Frontiers in Psychology, 8*, Article 805. https://doi.org/10.3389/fpsyg.2017.00805

Tian, N., Lopes, P., & Boulic, R. (2022). A review of cybersickness in head-mounted displays. *Virtual Reality, 26*(4), 1285–1302. https://doi.org/10.1007/s10055-022-00638-2

Truchly, P., Medvecký, M., Podhradský, P., & Vančo, M. (2018). Virtual reality applications in STEM education. In *Proceedings of the 16th IEEE International Conference on Emerging eLearning Technologies and Applications (ICETA 2018)* (pp. 597–602). IEEE. https://doi.org/10.1109/ICETA.2018.8572133

Valdez, M. T., Ferreira, C. M., & Barbosa, F. P. M. (2013). Distance education using a desktop virtual reality system. In *Proceedings of the 24th EAEEIE Conference* (pp. 145–150). IEEE. https://doi.org/10.1109/EAEEIE.2013.6576518

Yu, Y., Li, Y., Zhang, Z., Gu, Z., Zhong, H., Zha, Q., Yang, L., Zhu, C., & Chen, E. (2020). A bibliometric analysis using VOSviewer of publications on COVID-19. *Annals of Translational Medicine, 8*(13), 816. https://doi.org/10.21037/atm-20-4235

Zhang, Y., Liu, H., Kang, S. C., & Al-Hussein, M. (2020). Virtual reality applications for the built environment. *Automation in Construction, 118*, 103311. https://doi.org/10.1016/j.autcon.2020.103311