

# A bibliometric analysis of extended reality research trends in communication studies written in English: Mapping the increasing adoption of extended reality technologies

## *İngilizce iletişim çalışmalarında genişletilmiş gerçeklik araştırma eğilimlerinin bibliyometrik bir analizi: Genişletilmiş gerçeklik teknolojilerine gelişen rağbetin haritalanması*

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### Abstract

With the development of communication technologies, extended reality technologies and applications are increasingly favoured because of their potential to contribute to interactive digital experiences. In addition to providing information about objects, the integration of extended reality offers an enriched experience through a virtual layer that includes various interactions. This paper offers a quantitative and systematic review of studies published in the Web of Science Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Emerging Sources Citation Index (ESCI), and Arts & Humanities Citation Index (AHCI) on extended reality technology in communication studies in English between 1992 and 2023. Within the scope of this research, studies on the concepts of mixed reality, augmented reality, virtual reality, and extended reality in journals indexed in the Web of Science (WOS) database were searched. A total of 209 publications were included in the scope of the bibliometric analysis with filters for publication type, language, open access category, and subject. Bibliometric tools were employed to identify trends in extended reality and communication studies, including primary research topics and clusters, interdisciplinary distribution, productivity, and collaboration at the country level, keyword and citation networks, and co-occurrence networks. These findings contribute to the understanding of the evolution of extended reality research in communication studies and lay a foundation for further research.

**Keywords:** Extended reality, virtual reality, augmented reality, communication studies, bibliometric analysis

## **Öz**

İletişim teknolojilerinin gelişimiyle birlikte, genişletilmiş gerçeklik teknolojisi ve uygulamaları, etkileşimli dijital deneyimlere katkı sağlama potansiyelleri nedeniyle giderek daha çok tercih edilmektedir. Genişletilmiş gerçekliğin entegrasyonu, nesnelere hakkında bilgi sağlamanın yanı sıra sanal bir katman aracılığıyla zenginleştirilmiş ve çeşitli etkileşimleri içeren bir deneyim sunmaktadır. Bu çalışma, İngilizce dilinde gerçekleştirilmiş iletişim çalışmalarında 1992 ile 2023 yılları arasında genişletilmiş gerçeklik (extended reality) teknolojisi konusunda Web of Science Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Emerging Sources Citation Index (ESCI) ve Arts & Humanities Citation Index (AHCI) dizinlerinde yayımlanmış çalışmaların nicel ve sistematik bir incelemesini sunmaktadır. Araştırma kapsamında, WOS

veri tabanında endekslenen dergilerde karma gerçeklik, artırılmış gerçeklik, sanal gerçeklik ve genişletilmiş gerçeklik kavramları ile ilgili çalışmalar taranmıştır. Yayımların dili, açık erişim kategorisi ve konu filtreleri ile ulaşılan 209 yayının bibliyometrik analiz kapsamına dahil edilmiştir. Bibliyometrik araçlar, genişletilmiş gerçeklik ve iletişim çalışmalarındaki eğilimleri belirlemek amacıyla temel araştırma konuları ve kümeleri, alanlar arası dağılım, ülkeler bazında üretkenlik ve iş birliği, anahtar kelime ve alıntı ağı ve eşdizim ağlarını belirlemek için kullanılmıştır. Bulgular, genişletilmiş gerçeklik araştırmalarının iletişim çalışmalarındaki evrimini anlamaya katkıda bulunmuş ve gelecekteki araştırma çabaları için temel oluşturmuştur.

**Anahtar kelimeler:** Genişletilmiş gerçeklik, sanal gerçeklik, artırılmış gerçeklik, iletişim çalışmaları, bibliyometrik analiz

## Introduction

The integration of extended reality (XR, an umbrella term for technologies that merge the real and virtual worlds), including the modalities of virtual reality (VR, fully immersive digital environments), augmented reality (AR, the overlay of digital information onto the real world), and mixed reality (MR, the blending of real and virtual elements with interaction), has become increasingly prevalent across diverse fields, introducing innovative tools and methodologies. The implementation of XR technologies has been explored in diverse disciplines, including education, psychology, tourism, business, and computer science. The use of XR in these disciplines has demonstrated its potential to revolutionise traditional approaches, create immersive experiences, and enhance engagement across different contexts.

XR technologies have been explored for their enabling roles in enhancing learning experiences and engagement in education. Studies have explored the application of VR and AR in educational contexts, demonstrating their ability to attract students' attention, strengthen concentration, and improve academic achievement (Sirakaya & Çakmak, 2018; Wang et al., 2018; Steele et al., 2020). Furthermore, XR's integration into distance learning systems has shown a significant correlation between spatial skills and AR, highlighting its potential to transform open and distance learning (Altınpulluk, 2018). XR has also been recognised for its potential to promote novel and innovative learning experiences in higher education (Steele et al., 2020).

In psychology, XR technology has been leveraged to address various psychological and therapeutic challenges. Several studies have demonstrated the potential of VR to alleviate psychological distress; for instance, it has shown the effectiveness of VR in treating conditions such as gambling behaviour (Dickinson et al., 2020) and various anxiety and stress-related disorders through stress management (Matsangidou et al., 2020). Moreover, immersive VR experiences have been associated with assisting older adults, providing ways to promote health, and addressing social isolation and loneliness (Ferreira et al., 2022).

In tourism and business contexts, XR technologies have been applied to create AR experiences and offer innovative ways to engage and attract consumers (Rosanensi, 2020; Kyguolienė & Braziulytė, 2022). The integration of AR in product packaging has been analysed, showing its potential for advertising purposes and consumer engagement

(Kyguolienė & Braziulytė, 2022). XR has been integrated into e-commerce platforms to enhance effectiveness and user experience (Serrano et al., 2013).

In computer science and technology, XR technologies have been studied for their applications in various domains, including mathematics, artificial intelligence, and geospatial visualisation (Artut, 2019; Chung et al., 2020; Pavlenko et al., 2022). Research on the development of XR technologies demonstrates their potential to generate enhanced user experiences, highlighting the field's ongoing innovation and exploration (Dirgantoro, 2021).

The impact of XR on various disciplines extends beyond the aforementioned areas, encompassing fields such as arts, music education, history, and healthcare. XR technologies have been utilised to create immersive experiences in music education and to enhance the understanding of historical contexts through AR (Suparjoh et al., 2020).

In conclusion, the integration of XR technologies has significantly affected various disciplines by offering innovative tools and methodologies to enhance learning, address psychological challenges, transform consumer experiences, and advance technological applications. The diverse applications of XR in different disciplines underscore its potential to revolutionise traditional approaches and create immersive and interactive experiences across diverse domains.

### **Defining extended, augmented, virtual, and mixed reality**

XR, which includes MR, AR, and VR, describes a range of technologies that modify or create new realities. XR encompasses environments generated, enhanced, or manipulated using digital technology (Flavián et al., 2019). Mann and Wyckoff (1991) first used the term XR as an umbrella term for technologies that integrate both virtual and real elements. According to them, a basic form of XR involves a generalised real-time X-response that actively extends the human senses approximately 30 to 60 times per second, equivalent to 16 to 33 milliseconds. This is in contrast to the prolonged process of shooting the XR film and undergoing chemical development, which takes hours to observe the results. In this evolved XR concept, individuals can perceive the world through a specific viewer created from a VR Head-Mounted Display (HMD) connected to specialised television cameras (Mann & Wyckoff, 1991). XR applications include

various levels of immersion, from fully digital VR environments to MR and AR, in which virtual elements are superimposed on the user's perception of reality (Tham et al., 2018).

Milgram and Kishino (1994) employ the theory of "Reality-Virtuality Continuum" to categorise VR, AR, and MR concepts. Within this continuum, VR refers to an environment in which the user's relationship with the world is completely severed after entering, in contrast to AR, which maintains a connection with the real world by seamlessly integrating data and images into the real-world view (Milgram & Kishino, 1994). Milgram and Kishino's (1994) groundbreaking work established MR as an encompassing term that integrates both virtual and genuine features. Scholarly discourse on this notion varies, with some challenging perspectives from Milgram and Kishino. According to some scholars, MR is a unique form of reality that falls between AR and "augmented virtuality (AV)" (Farshid et al., 2018; Flavián et al., 2019).

Hoyer et al. (2020) broadened the discussion by suggesting that MR functions as an expansion of AR, arguing that AR is typically accessed through smartphone applications, while MR calls for a headset or a comparable wearable device. In addition, some authors have emphasised the fundamental differences between AR and VR (Tan et al., 2022). Adding complexity to the discussion, Milgram et al. (1995) note, "Perhaps surprisingly, we do, in fact, agree that AR and VR are related and that it is quite valid to consider the two concepts together" (p. 283).

VR is characterised as an artificial environment crafted to make a user feel an integral part of the environment. AR entails the integration of digital elements into an individual's actual environment, which is achieved through various means, such as computer-generated imagery, digital animation, and 3D graphics. MR, also known as XR, is a technology that integrates artificially created content with the physical world by utilising holograms that are projected into the user's environment and possess interactive capabilities. (Montoya et al., 2018; Muñoz-Saavedra et al., 2020).

Jaron Lanier introduced the term "virtual reality" in 1989, which includes three-dimensional environments experienced through stereo-viewing goggles and reality gloves (Krueger, 1991). Lanier (1989) conceptualised technology as a computer-simulated environment in which people can engage. By employing visual, aural, and haptic devices, users can immerse themselves in a synthetic environment and experience it

as if they were integral parts of that world. The integration of motion and response sensing input devices into computers enables the creation of a dynamic, interactive, and immersive synthetic environment in real time, providing the illusion of active engagement within the virtual world (Riva et al., 2007).

Despite the common characterisation of VR as a specific array of technological hardware, it is equally possible to articulate the concept of VR experience, particularly by employing the notion of presence (Steuer, 1992). According to Greenbaum (1992), this is an alternate reality consisting of computer-generated images that respond to human movements, which are typically accessed through expensive data suits outfitted with stereophonic video goggles and fibre-optic data gloves. Communication studies often fail to provide meaningful insights to researchers, software developers, policymakers, and media consumers because of the conventional depiction of VR as a technological medium. This hardware-centric focus, which emphasises computers, HMDs, headphones, and motion-sensing gloves, is primarily geared towards hardware producers. However, according to Steuer (1992), such a device-driven conceptualisation is inadequate for understanding the experiential aspects, processes, and effects of VR systems.

The pivotal notion in defining VR lies in the concept of “presence.” Presence, as proposed by Gibson (1979), goes beyond physical surroundings in the real world; it encloses the interpretation of physical surroundings through a combination of automatic and controlled mental processes. This perspective emphasises the experiential aspect of VR, offers a framework for regulatory decisions, media product creation, and consumer understanding, and provides users with immersive three-dimensional experiences through HMDs (Coates, 1992).

AR is described as a technology that merges real-world and virtual visuals, facilitating synchronous interaction between real and virtual entities (Azuma, 1997). According to Azuma (1997), AR is a variation of virtual environments. The term denotes technology that enhances a user’s perception of the real world by presenting information perceived as part of the spatial environment (Azuma et al., 2001, p.45). AR involves the combination of real-world and computer-generated data, including graphics, video, sound, animation, and information on Global Positioning System (GPS) location (Zachary et al., 1997). AR applications enable the independent and simultaneous use of virtual objects, such as 3D elements, text, images, videos, and animations (Wang et al., 2013), allowing users

to interact naturally with objects, information, and actions (Wojciechowski et al., 2004; Wojciechowski & Cellary, 2013). Three key features distinguish AR, as highlighted by Azuma (1997) and Moreno, MacIntyre, and Bolter (2001) are; the integration of virtual and real objects, real-time interaction, and incorporation of 3D objects.

While the concept of AR has its roots in the 1950s, it was termed Tom Caudell in the 1990s. Caudell pioneered the development of AR technology to guide workers during the installation of electrical cables on aeroplanes, thereby creating a head-mounted digital imaging system (Caudell & Mizell, 1992; Siltanen, 2012). Craig (2013) outlined the elements of AR, emphasising its augmentation of the physical world by adding digital information, reflecting information in relation to the real world, shaping displayed information based on the physical world's location and viewers, and enabling interactive experiences. AR technology has gained widespread usage in various sectors, including education, health, architecture, art, and marketing, since the early 2000s. It is used across various platforms, including desktop computers, laptops, tablets, and smartphones (Kirner et al., 2012). Potential and existing applications of AR include entertainment, gaming, cultural heritage, education and training, tourism, social networking, and marketing (Gervautz & Schmalstieg, 2012).

### **Extended reality research**

XR, which includes VR, AR, and MR, has emerged as a transformative technology with diverse applications across various disciplines. The literature on VR research encompasses various topics such as immersion, presence, learning outcomes, assessment tools, gaming, and the impact of VR on behaviour and cognition. Studies have directly related the sense of 'presence', 'immersion', and 'flow' in various VR interfaces with favourable learning results (Hamari et al., 2016). This finding indicates that VR has been investigated for its impact on learning and engagement. Additionally, researchers have explored the challenges of VR-based assessment tools compared with traditional measures, indicating the necessity for meta-analytic approaches to comprehend the cumulative findings of research in this area (Neguț et al., 2016). This highlights the rigorous examination of VR as an assessment tool and the complexity of its implementation.

Furthermore, VR has been investigated in the context of its impact on various behaviours and experiences. For example, studies have explored the effects of VR on perceived enjoyment, value, behavioural intention, and its influence on gambling

behaviour (Lee, Chung & Lee, 2013; Dickinson et al., 2020). These studies demonstrate the diverse range of behaviours and experiences examined in relation to VR. The potential of VR as a diagnostic tool for social anxiety has been explored, indicating its potential applications in mental health research (Dechant et al., 2017). Additionally, the impact of VR on creative performance and emotions has been studied using brainwave analysis, demonstrating its potential to enhance creativity and emotional experiences (Huang & Chang, 2023).

The literature also discusses the technological aspects of VR, such as its use in navigation, spatial training, and the design of immersive learning environments (Chang et al., 2015; Montag et al., 2021). This indicates the multidisciplinary nature of VR research, which encompasses fields such as human-computer interaction, education, and cognitive psychology. In addition to its application in research and education, VR has been studied in the context of consumer behaviour, shopping experiences, and the impact of VR on product interactions and purchase decisions (Serrano et al., 2013; Kerrebroeck et al., 2017; Lombart et al., 2020; Bigne, 2024). These findings indicate that VR has commercial and marketing implications.

Furthermore, the ethical and societal implications of VR have been explored, including its impact on sociopolitical attitudes, socialisation, and the potential for escapism from real-world experiences (Bacovsky, 2020). This indicates that VR research extends beyond technical and psychological aspects to encompass broader societal and cultural considerations. Overall, the literature on VR research is extensive and multidisciplinary and addresses a diverse array of topics and applications. This reflects the diverse and evolving nature of VR as a subject of study, encompassing its technological, psychological, commercial, and societal dimensions.

AR has attracted considerable attention from academic literature across various disciplines, reflecting its diverse applications and implications. The literature on AR encompasses various topics, including technology acceptance, user engagement, educational applications, and their impact on social and cultural aspects. A particular area of investigation revolves around the impact of AR attributes on technology acceptance. McLean and Wilson (2019) introduced a new set of AR attributes, such as AR novelty, interactivity, and vividness, and established their impact on technology acceptance factors such as perceived ease of use and usefulness. This study illuminates the factors that influence the adoption and acceptance of AR technology.



AR has demonstrated effectiveness in increasing user engagement and enhancing the overall experience. Its use at science festivals as part of the broader “experience economy” trend shows AR’s power to create memorable interactions across diverse applications (tom Dieck et al., 2018).

AR has been explored in the field of education because of its potential in vocational training and early literacy. Liao and Humphreys (2014) defined AR as a technology that blends a real environment with a virtual environment to provide interactive and immersive experiences (Liao & Humphreys, 2014). Studies have also focussed on the development of AR-based systems for teaching and treating specific phobias, highlighting their potential in educational and therapeutic settings (Drigas et al., 2015; Wrzesien et al., 2015; Belo et al., 2016).

The literature examines the ways in which and are shaped by society and culture (Liao, 2016). Liao’s work, drawing on “sociology of futures” theories, emphasises the dynamic interplay between technological development and its prospective impact on the future. Moreover, the impact of AR on social media use, well-being, and family connectedness has been subject to systematic and critical scoping reviews, reflecting increasing interest in understanding the effects of AR on both individuals and society (Hawk et al., 2008; Tariq et al., 2021; Ronzhyn et al., 2022).

In addition to its applications, AR has been examined in the context of gaming, location-based experiences, and its potential to induce cooperation. Shaikh and Karjaluoto (2015) emphasised the importance of domain-specific literature reviews to advance research and open new possibilities for future studies. This highlights the need for specialised studies to explore the diverse applications and implications of AR in specific domains. Furthermore, the literature has addressed technological advancements, the intersection of AR and artificial intelligence, anime culture, and digital media tools, thus reflecting the interdisciplinary nature of AR research (Melchior & Oliveira, 2021; Liu & Wu-Ouyang, 2022).

Overall, the literature on AR is multidisciplinary, encompassing technology acceptance, user engagement, educational applications, societal and cultural implications, and convergence with other technological domains. The diverse range of topics and applications reflects the evolving nature of AR as a subject of study, with implications for various fields and domains. The literature review of XR research in communication

studies highlights the multidisciplinary nature, evolving use, and understanding of XR technologies, underscoring their potential to revolutionise traditional approaches and create immersive experiences in diverse domains.

## **Aim and methodology**

This study explored XR research in communication studies between 1992 and 2023. A bibliometric analysis was conducted to provide an extensive comprehension of this domain and reveal academic trends in the field. This type of analysis is a scientific, computer-assisted investigation methodology designed to discern fundamental research or authors and elucidate their relationships. This method achieves its objective by comprehensively reviewing all publications associated with a particular topic or field (De Bellis, 2009). Bibliometrics encompasses a collection of methods used to measure and evaluate academic output (Cobo et al., 2011). As outlined by Merediz-Solà and Bariviera (2019), this involves statistical analysis of publications within a particular research field. This approach seeks to map the current state of research in this field quantitatively and impartially.

The research methodology employed in this study utilised bibliometric tools to examine and elucidate the volume, attributes, and productivity of XR and communication studies. The application of bibliometric methods facilitates the systematic examination and assessment of the research field. This study used bibliometric methods to investigate the progression of XR and communication fields. With these objectives in mind, this study addressed the following research questions:

- Q1:** What is the progression of XR research within the realm of communication studies over time?
- Q2:** Which countries exhibit the highest productivity, and how is the international collaboration framework structured?
- Q3:** Which journals demonstrate the highest productivity in the field of research?
- Q4:** Who are the most productive authors in this field?
- Q5:** What are the most frequently used keywords, and how are these keywords clustered?
- Q6:** What is the intellectual framework of the research field based on the co-citation network of authors and journals?
- Q7:** Which articles received the highest number of citations in the research field?

These research questions were designed to comprehensively explore various aspects of XR in communication studies, ranging from historical development to key contributors, journals, keywords, and trends within the field.

The trends in the literature that constitute the subject of the research are examined using keyword research conducted via WOS, utilising the terms 'mixed reality,' 'augmented reality,' 'virtual reality,' and 'extended reality' combined with the operator 'OR'

The search was conducted without time limitations to retrieve records that matched the query in the titles. No time constraints were applied, and all available years in the database were included. Data were retrieved on February 3, 2024. Initially, the keywords in the titles yielded 97.597 results. After restricting the document type to articles and review articles, language to English, and WOS categories to communication, and excluding green-published and green-submitted articles, the results were narrowed to 589 articles.

In the next step, the meso topics of Human-Computer Interaction, Communication, Management, Social Psychology, Sociology, Bibliometrics, Scientometrics, and Research Integrity were chosen, along with the SCI-EXPANDED, SSCI, ESCI, and AHCI. This refinement resulted in 285 articles. Following a thorough evaluation of the abstracts of the articles, the selection process resulted in a final dataset comprising 209 publications spanning 1992–2033.

A comprehensive search for publications related to the research topic was conducted in the WOS, and the results were analysed. A literature-specific framework was constructed on the basis of studies conducted on the subject. The acquired data were analysed using RStudio, Bibliometrix, and VOSviewer. RStudio, functioning as an integrated development environment for R, a programming language specialising in statistical calculations and graphics, facilitates statistical computations and visualisation. Bibliometrix, developed by Aria and Cuccurullo in 2017 for the R statistical programming language, is a package designed for the quantitative analysis of publications, including citation numbers associated with journal articles (Aria & Cuccurullo, 2017). The VOSviewer tool was employed for the bibliographic processing of key findings and plays a pivotal role in the analysis. This freeware programme was designed to process and map bibliometric data, thereby contributing to a comprehensive exploration of the research landscape.

Various bibliometric methods, including citation, co-occurrence, and co-citation analysis, have been utilised to comprehensively map the research field. This study relies on a descriptive analysis, including the number of titles, citations, research areas, and corresponding sources, to establish a foundation. The number of publications served as an indicator of productivity in the research field. In addition, the study incorporated a bibliographic map featuring the most frequently used titles and abstract words along with author and country productivity. To enhance the structure of the subject area, co-citation maps of the authors and their sources were generated using VOSviewer and Bibliometrix. Finally, the 20 most frequently cited articles are listed. The results offer an intellectual framework for this research field and discuss the research themes and their temporal evolution.

## Findings

The analysis of articles published in indexed journals provided a statistical framework for this study. The earliest article in the dataset was published in 1992, with no increase in publication count observed until 2014. However, since 2014, there has been a notable increase in interest in XR research in the communication field. Articles published between 2014 and 2023 represent 80.8% of the total literature in the dataset.

The analysis revealed that 209 articles authored by contributors from 38 countries were published in 79 different journals from 1992 to 2023 (Table 1). In addition, among these articles, 72 single-author studies were published by 65 authors, and the cumulative number of authors across all studies reached 436. Furthermore, the average co-authorship per document was calculated to be 2.38, with international co-authorship accounting for 16.27% of collaborations.

**Table 1.** Descriptive statistics of the articles

Description	Results
Period	1992-2023
Sources (Journals)	79
Total documents	209
Articles	209
Average citations per document	31.69
Authors	436
Single-authored documents	72
Authors of single-authored documents	65

Co-authors per document	2.38
International co-authorships (%)	16.27
Author's keywords (DE)	693

Table 2 illustrates the distribution of articles published by these sources. Specifically, one journal published 20 articles, whereas the other published 14. Additionally, two journals each had 10 articles, seven articles, and six articles, whereas two journals published five articles each. Of the 79 journals examined, 39 published only one article each, whereas 18 published two articles each. Consequently, it is noteworthy that 72.1% of the journals contributed few articles to the literature.

**Table 2.** Number of articles and source frequency

	<b>Number of articles</b>	<b>Source (Journal) frequency</b>
	1	39
	2	18
	3	4
	4	8
	5	2
	6	2
	7	2
	10	2
	14	1
	20	1
Total	209	79

### **Publications per relevant fields**

Table 3 displays the distribution of publications across various relevant fields. It is crucial to note that the dataset was restricted to literature in the field of communication. Psychology has emerged as the most relevant field in XR research in communication studies, followed by business economics and film, radio, and television.

**Table 3.** Number of publications per relevant field

Discipline	Number of records	% of 209
Communication	209	100%
Psychology	23	11%
Business Economics	17	8.1%
Film Radio Television	14	6.7%
Sociology	9	4.3%
Cultural Studies	8	3.8%
Information Science and Library Science	5	2.4%
Engineering	4	1.9%
Education Educational Research	2	1%
Environmental Sciences and Ecology	1	0.5%
Health Care Sciences Services	1	0.5%
Women Studies	1	0.5%

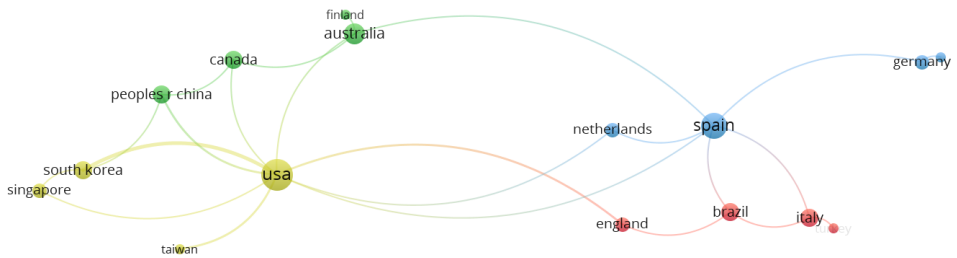
### Most productive countries and country collaboration networks

Table 4 provides insights into the countries most actively involved in XR research within the communication field, considering both publication frequency and citation impact. The data, derived from the affiliation addresses of the respective authors, emphasise the ten most productive and influential countries. Notably, the United States (USA) emerged as the most productive country, with 93 publications and 2199 total citations, followed by Australia and Spain.

**Table 4.** The 10 most productive and influential countries (VOSViewer)

Country	Number of articles	Total citations
United States (USA)	93	2199
Australia	20	277
Spain	16	697
South Korea	13	422
Netherlands	9	115
Germany	9	107
Canada	8	53
Finland	6	32
Taiwan	5	35
United Kingdom	5	85

Figure 1 illustrates the network of countries that showcase international collaboration within the research field. VOSviewer identifies relevant data from 38 countries, with 16 countries forming clusters. The size of the bubbles indicates the dominance of countries in XR research in communication studies, whereas the line weights represent the collaboration strength between those countries. Additionally, different bubble colours signify clusters, with yellow cluster countries representing those that collaborate most frequently. From the network, it is evident that the United States and South Korea exhibit the strongest ties in terms of XR publications.



**Figure 1.** Mapping of country collaboration

### Most productive journals and co-citation analysis of journals

Table 5 presents the 15 most productive journals in the field of research. According to the table, the three most productive journals are *New Media and Society*, *Convergence—The International Journal of Research into New Media Technologies*, and *Cyberpsychology and Behavior*. The initial publication related to this subject matter appeared in 1992 in the *Journal of Communication*, which was also the most cited journal. *New Media and Society* began publication in 2002, while *Convergence—The International Journal of Research into New Media Technologies* debuted in 2012. The first publications in the remaining journals occurred after 2000, with a particularly noticeable upward trend after 2013.

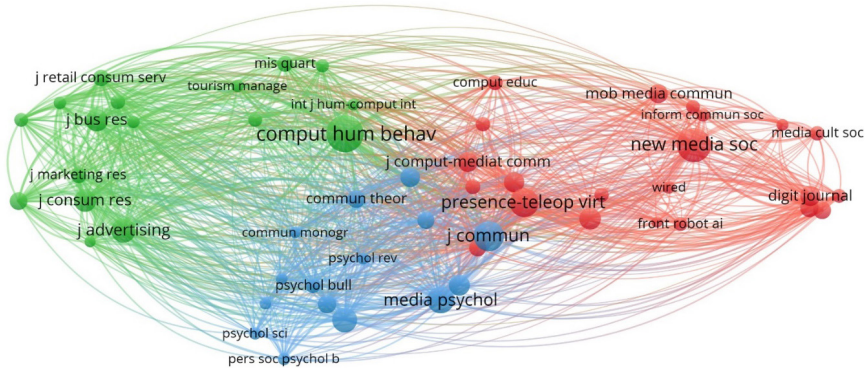
**Table 5.** The most productive journals (VOSviewer)

Journals	Articles	Citations	First publication year*
New Media and Society	20	599	2002
Convergence-The International Journal of Research into New Media Technologies	14	81	2012
Cyberpsychology & Behavior	10	164	2000
Mobile Media & Communication	10	746	2013
Information Communication & Society	7	155	2013
International Journal of Advertising	7	148	2017
Journal of Communication	6	2869	1992
Media Psychology	6	234	2008
Digital Journalism	5	149	2020
Journalism Studies	5	84	2019
Media International Australia	4	74	2017
Journal of Current Issues and Research in Advertising	4	43	2019
Critical Studies in Media Communication	4	22	2000
Journal of Advertising	3	408	2002
Journalism Practice	2	24	2021

\*The first publication year indicates the year in which the study of XR research in communication studies was first published in a relevant journal.

The co-citation analysis of the journals illustrated in Figure 2 provides an in-depth overview of the subject fields. A minimum threshold of 20 citations for a source was chosen, resulting in 54 of 5448 sources meeting these criteria. The size of the bubbles indicates the number of citations received by the journal, whereas the line weight represents the link strength. The proximity and connectivity between the two journals determine the co-citation relationship. Additionally, the colors of the circles signify clusters, categorizing journals into three clusters based on their common characteristics. The green cluster comprises journals dominant in computer-human interactions within communication, management, and marketing. The red cluster consists of journals that focus on new media and computer technology-oriented communication studies. The blue cluster in the middle consists of journals investigating human behavior and psychology within XR research in communication studies.





**Figure 2.** Journals co-citation map (Treshhold:20 / Out of 5448 identified sources, 54 sources met the treshold)

### Author publication, citation, and co-citation analysis

Information regarding authors’ productivity is presented in Table 6. Based on the table, Kim emerged as the most productive author in terms of the number of articles contributed. Upon closer examination of the number of authors listed in the articles, Biocca became the first author with the highest number of articles fractionalized. This observation highlights the impact of authorship order on individual contributions. The number of authors in an article decreases, and the fractionalized effect of each author’s contribution may increase, even if the total number of articles authored by an individual decreases.

**Table 6.** The most productive authors

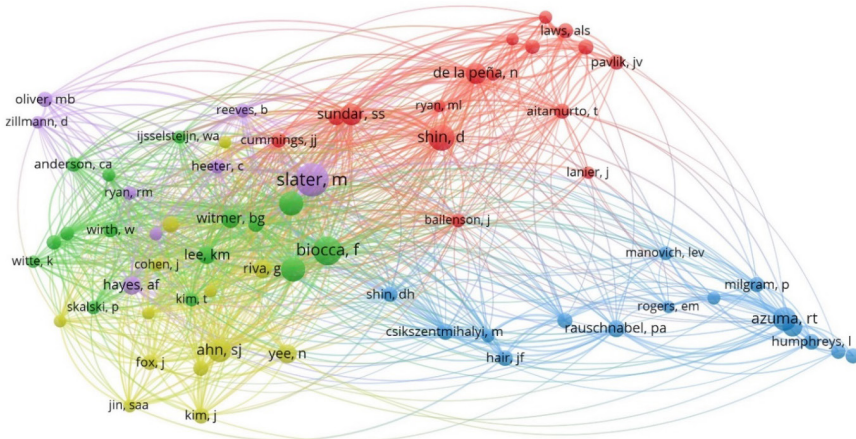
Authors	Articles	Authors	Articles fractionalized
Kim, J	7	Biocca, F.	3.33
Ahn, S.J.G.	5	Kim, J	2.73
Biocca, F.	5	Liao, T.	2.70
Carter, M.	4	Carter, M.	2.00
Egliston, B.	4	Egliston, B.	2.00
Liao, T.	4	Dowling, D.O.	2.00
Wu, D.Y.	4	Harley, D.	2.00
Lin, J.H.T.	3	Irom, B.	2.00
Bailenson, J.N.	2	Rantakokko, S.	2.00
Best, K.	2	Wu, S.	2.73

Table 7 shows the impact of the most productive 10 authors. Carter and Egliston stand out as the most notable authors based on the M-index, which represents the median number of cited publications. Despite the commencement of research in 2022, their impact is rapidly increasing. However, Kim ranked first in terms of the G-index. With seven articles and starting production in 2015, the author also demonstrates a significant impact, with the potential for further effectiveness as time progresses.

**Table 7.** Impact of the most productive 10 authors

Author	H-index	G-index	M-index	Total citations	Number of paper	First publication year
Biocca, F.	5	5	0,152	674	5	1992
Ahn, S.J.G.	4	5	0,571	46	5	2018
Carter, M.	4	4	1,333	62	4	2022
Egliston, B.	4	4	1,333	62	4	2022
Kim, J.	4	7	0,4	53	7	2015
Liao, T.	3	4	0,3	93	4	2015
Bailenson, J.N.	2	2	0,5	16	2	2021
Best, K.	2	2	0,167	10	2	2013
Butler, S.	2	2	0,167	10	2	2013
Daviz, D.Z.	2	2	0,333	17	2	2019

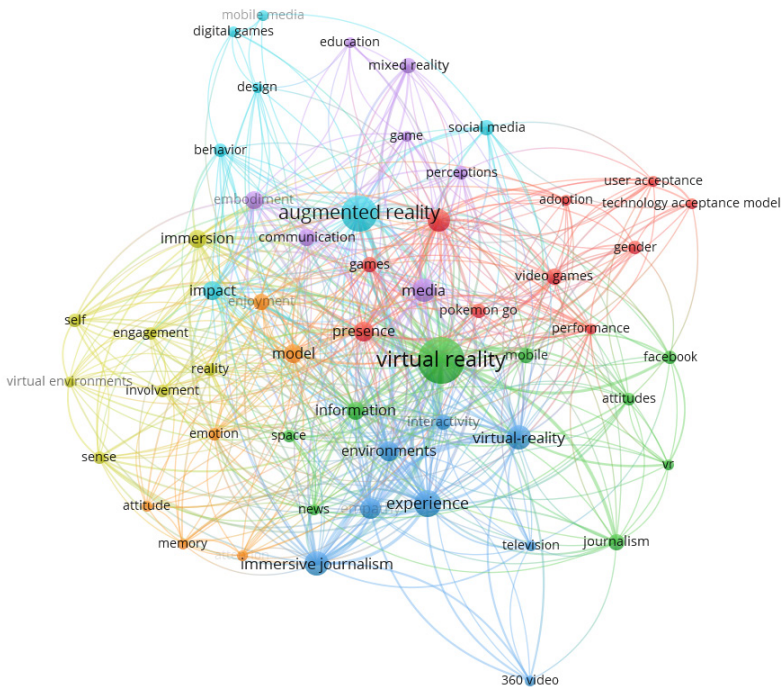
Figure 3 illustrates the co-citation network of authors within the XR research field. A citation threshold of 10 was set to ensure the display of relevant articles. Of the 6.831 authors in the dataset, 67 met the threshold criterion. This figure highlights the intellectual roots of the research topics associated with the authors, leading to the identification of the five main clusters. In the purple cluster, Slater emerged as the most frequently cited author with 71 citations, focusing primarily on the concepts of presence and immersion in virtual environments. Biocca achieved the highest number of citations in the green cluster, with 53 citations, with a research background mainly covering VR research in communication. Shin stands out in the red cluster, cited most frequently with 43 citations, exploring the concept of immersion, especially in AR games, from a user-centered perspective. Ahn was the most frequently cited author in the yellow cluster, with 36 citations attributed to their work. Finally, in the blue cluster, Azuma received the highest number of citations, with 36 citations.



**Figure 3.** Author co-citation map (Treshhold:10 / Out of 6831, 67 met the treshhold)

### Keyword analysis and co-occurrence network

Figure 4 shows the co-occurrence analysis and its connections. Following the approach of Vallaster et al. (2019), a threshold of five was set to display the keywords. This threshold determines the frequency at which a keyword appears in an article within the dataset to be considered in the analysis. Visualized by VOSviewer, the co-occurrence analysis organizes the research field into clusters. The size of the bubbles represents the frequency of keyword occurrence in the articles. A closer proximity of keywords indicates a stronger relationship between the terms (Alonso et al., 2009).



**Figure 4.** Keyword (all keywords) co-occurrence map (Min:5 / Out of 968, 54 met the threshold)

A total of 209 studies were analyzed using VOSviewer, based on keywords. The resulting individual clusters were color-coded according to subject areas, with VR and AR emerging as the main clusters in XR in the communication research field. Figure 4 highlights the most frequently used keywords. The green cluster primarily focused on the concept of XR, with the keyword ‘virtual reality’ appearing 82 times at the center and comprising the most references. VR is commonly associated with keywords such as information, journalism, attitudes, mobile, news, space, and *Facebook*. In the light blue cluster, the most referenced and central term is ‘augmented reality’ which is closely linked to other clusters. Related terms include impact, social media, behavior, design, digital games, and mobile media. The dark blue cluster emphasizes the ‘experience’ in XR research, adopting a perspective on topics such as immersive journalism, VR, environments, empathy, interactivity, television, and 360 videos. The purple cluster focuses on ‘media’, combining terms like communication, perceptions, embodiment, game, MR, and education. The red cluster centers around ‘technology,’ addressing terms such as presence, games, video games, performance, adoption, and acceptance. The yellow cluster explores ‘immersion,’ combining terms such as involvement, engagement,

and reality. Lastly, the orange cluster centers on the term 'model,' incorporating terms like enjoyment, emotion, attitude, memory, and attention.

Table 8 provides supplementary information to Figure 4 by presenting the values of the most significant 20 keywords in the dataset, organized based on the strength of their total links. This illustrates the frequency of the occurrence of particular keywords in publications. As shown in Table 8, VR and AR were the most frequently used keywords in XR research in communication studies. In addition, terms such as immersive journalism, presence, immersion, and embodiment were included in the articles.

**Table 8.** The most frequent author keywords

Keyword	Occurrences	Total link strength
Virtual reality	88	101
Augmented reality	44	37
Immersive journalism	21	38
Presence	15	26
Immersion	11	26
Embodiment	10	16
Empathy	9	17
Mixed reality	8	13
Video games	7	12
Technology	6	16
Journalism	6	12
Facebook	5	17
Gender	5	10
Social media	5	6
Oculus	4	14
Metaverse	4	10
VR	4	10
Extended reality	4	9
Interactivity	4	9
Telepresence	4	9

Table 9 lists the 20 most frequently cited articles in the dataset. These articles, characterized by their high citation numbers, shed light on specific research trends within the XR domain. Notably, the article "Defining virtual reality: Dimensions determining telepresence" by Steuer (1992) gathered the highest number of citations. Among the 20 most frequently cited articles, a significant portion was dedicated to VR

research.

**Table 9.** The most cited articles (VOSviewer)

Author(s) (year)	Title	Source	Total citations	Total citations per year
Steuer (1992)	Defining virtual reality: Dimensions determining telepresence	Journal of Communication	2547	77.18
Riva et al. (2007)	Affective interactions using virtual reality: The link between presence and emotions	Cyberpsychology & Behavior	554	30.78
Li, Daugherty, and Biocca (2002)	Impact of 3-D advertising on product knowledge, brand attitude, and purchase intention: The mediating role of presence	Journal of Advertising	390	16.96
Shin and Biocca (2018)	Exploring immersive experience in journalism	New Media & Society	138	19.71
Regian (1992)	Virtual reality: An instructional medium for visual-spatial tasks	Journal of Communication	128	3.88
Gillath, McCall, Shaver, and Blascovich (2008)	What can virtual reality teach us about prosocial tendencies in real and virtual environments?	Media Psychology	83	4.88
Shin (2017)	How does immersion work in augmented reality games? A user-centric view of immersion and engagement	Information Communication & Society	82	13.67
Lee, Chung, and Lee (2013)	Presence in virtual golf simulators: The effects of presence on perceived enjoyment, perceived value, and behavioral intention	New Media & Society	79	6.58
Biocca (1992)	Communication within virtual reality: Creating a space for research	Journal of Communication	71	2.15
Tamborini et al. (2004)	Violent virtual video games and hostile thoughts	Journal of Broadcasting & Electronic Media	70	3.33
Lanier and Biocca (1992)	An insider's view of the future of virtual reality	Journal of Communication	68	2.06
Van Damme et al. (2019)	360° video journalism: Experimental study on the effect of immersion on news experience and distant suffering	Journalism Studies	63	10.50
Laws (2017)	Can immersive journalism enhance empathy?	Digital Journalism	62	12.40
Liao and Humphreys (2014)	Layar-ed places: Using mobile augmented reality to tactically reengage, reproduce, and reappropriate public space	New Media & Society	56	5.60
Eastin and Griffiths (2006)	Beyond the shooter game - Examining presence and hostile outcomes among male game players	Communication Research	56	2.95
Baek, Yoo, and Yoon (2018)	Augment yourself through virtual mirror: the impact of self-viewing and narcissism on consumer responses	International Journal of Advertising	55	7.86

Vella et al. (2019)	A sense of belonging: Pokemon Go and social connectedness	Games and Culture	53	8.83
Wagler and Hanus (2018)	Comparing virtual reality tourism to real-life experience: Effects of presence and engagement on attitude and enjoyment	Communication Research Reports	51	7.29
Bonus et al. (2018)	Look on the bright side (of media effects): Pokemon Go as a catalyst for positive life experiences	Media Psychology	50	7.14
Bollmer (2017)	Empathy machines	Media International Australia	50	6.25

## Discussion and conclusion

This study was conducted to address the interdisciplinary gap and discover emerging concepts in communication studies by providing a comprehensive bibliometric analysis of XR research trends, demonstrating the work around which communication scholars gather and form clusters. By systematically reviewing and synthesizing the existing literature, it highlights the major antecedents, trends, and factors significant to XR in communication studies, maps them onto models, and offers a future research agenda by elucidating tendencies to strengthen this emerging field. This holistic approach offers insight into the interdisciplinary nature of XR research in communication studies and its applications.

XR technologies, including AR and VR, are significantly transforming how people work, learn, connect, and play by merging physical and digital worlds. XR applications span various fields, including tourism, education, retailing, gaming, and healthcare (Kerawalla et al., 2006; Jung et al., 2015; Glegg et al., 2016; Rauschnabel et al., 2017; Yim et al., 2017). XR technologies were chosen because of their profound impact on enhancing communication by providing immersive and interactive experiences. They allow people to experience a sense of presence and realism, which are crucial for effective communication in digital environments (Suh & Prophet, 2018).

The integration of XR technologies within communication studies is transforming the field by introducing new tools and methodologies while emphasizing the concepts that enhance human interaction with media and simulation technologies. The most frequently cited articles, Steuer's (1992) article on defining VR and the dimensions determining telepresence, and Riva et al.'s (2007) affective interactions using VR show the prevalence of VR research which emphasizes its impact on presence and immersion, concepts that



intersect with communication studies. VR's ability to create fully immersive environments (Herz and Rauschnabel, 2019) and AR's potential to enhance real-world experiences with digital overlays (tom Dieck et al., 2018) have made them focal points of study.

The integration of AR into educational settings has shown its potential to enhance learning experiences align with theories of media richness (Huang & Liu, 2014) and cognitive load (Hsu, 2017; Sirakaya & Çakmak, 2018; Wang et al., 2018; Steele et al., 2020). Moreover, the uses and gratifications theory explains why users are drawn to XR technologies, highlighting their ability to satisfy diverse needs, such as entertainment, social interaction, and information seeking (Rauschnabel, 2018a; Rauschnabel, 2018b). Methodologically, XR technologies enable more sophisticated and immersive experimental designs (Hily et al., 2023), allowing researchers to study the communication processes in highly controlled virtual environments. These trends indicate a shift towards more interactive and immersive communication modalities, driving future theoretical developments in the field and underscoring the growing emphasis on VR and AR, which have the potential to enhance user engagement and interaction, which is crucial for developing effective communication strategies.

The most frequently used keywords in XR research were 'virtual reality' (88 occurrences) and 'augmented reality' (44 occurrences), indicating their dominance in the field. Other significant keywords include 'immersive journalism,' 'presence,' and 'immersion.' Immersive journalism encompasses both presence and immersion as communicative practices. By giving the audience a first-person account of events, this method seeks to increase empathy and engagement by giving them the impression that they are active participants rather than passive audiences (De la Peña et al., 2010), signalling a new domain for communication scholars to explore. For presence, according to Lee (2004), it happens when people who utilize technology are unaware of its virtual nature. Feeling of being there (Cummings & Bailenson, 2015) and being moved into narratives (Green & Donahue, 2012) are the critical constituents of presence which are shaped by sensory and cognitive faculties. Immersion, which can be thought of as a blurment of the experiences and identities between the physical and virtual worlds (Snodgrass et al., 2013), or a psychological state in which a person loses themselves in a digital environment and ignores cues from the real world (Fox et al., 2009), adds another working domain to the interactive nature of digital media. This informs communication studies regarding the contexts in which they are conducted, the communicative practices involved, and the methods of meaning-making and message conveyance.



In this context, McLuhan's (1964) conception of the electric age seems particularly relevant; people see themselves as being translated into information, moving toward a technological extension of consciousness. By integrating the physical bodies within these extended nervous systems through electric media, people establish a dynamic in which previous technologies—extensions of hands, feet, and bodily controls—are translated into information systems. XR technologies take this metaphor one step further. It alters the positioning of the media and consumer as two systems in which two information flows feed each other. This mutual translation of physical and social interactions in immersive digital experiences further blurs the lines between reality and virtuality.

Despite the promising outlook, the adoption of XR technologies has been slower than expected (Cranmer et al., 2016), due to technical limitations, cost, and performance issues, leading to fragmented scholarly work and insights that are yet to be fully translated into practice (Ratcliffe et al., 2021; Rauschnabel et al., 2022). Existing studies often focus on technological aspects, neglecting other factors, such as socio-cultural implications and user perceptions of XR technologies (Herz & Rauschnabel, 2019), and interdisciplinary relationships. However, with the consumer products that are now widely available to public (e.g. Meta's Quest headset, and Apple Vision Pro goggles) are changing the pace of acceptance with these technologies since the entertainment is one of the key trends in adopting the XR technologies (Ziker et al., 2021). Technological advancements have made VR and AR more accessible and practical, leading to their widespread adoption in industries as well as among consumers. This signals a correlation between the increasing number of publications after 2014 and technological accessibility.

This bibliometric analysis of XR research in communication studies from 1992 to 2023 highlights the growing interest and diverse applications of XR technologies. The findings underscore a significant uptick in publications post-2014, indicating a growing scholarly interest in XR's potential across various domains. An examination of 209 articles revealed that XR research in communication predominantly intersects with psychology, business economics, and media studies, illustrating the interdisciplinary appeal of XR technologies. USA, Australia, and Spain have emerged as leading contributors, reflecting a geographically diverse research community.

The analysis demonstrated the field's evolution, thematic orientation, and geographical distribution of research across a dynamic landscape. Despite these

contributions, this study has certain limitations that are inherent to its methodological choices and scope. Primarily, reliance on specific databases to curate the research corpus introduces a selection bias, potentially omitting significant publications not indexed within these platforms or those published in languages other than English. The exclusive use of English sources creates a limited research universe, facilitating discourse primarily within English-speaking contexts while constraining the discussions from non-English-speaking regions. The findings also reveal a geographical and institutional concentration of research output, predominantly in technologically advanced or research-intensive countries such as the USA, Australia, and Spain, thereby possibly overlooking contributions from other regions. Moreover, while the interdisciplinary nature of XR research in communication studies is highlighted, the complexity of such collaborations may not be fully explored, underscoring the need for a deeper investigation into their impact on the field's evolution.

Current trends in XR research will likely lead to the development of new theoretical frameworks that incorporate the effects of immersion and presence on communication. Future studies might also focus on cross-cultural comparisons to understand how diverse cultural contexts influence XR experiences and communication practices (Jung et al., 2015). As these technologies become more available, they require continuous investigation and collaboration (Querioz et al., 2024) as well as an understanding of the ethical implications of XR, such as privacy concerns and psychological effects (Slater et al., 2020).

Future bibliometric analysis could benefit from incorporating a broader array of databases, including multilingual research outputs, to mitigate selection bias and to provide a more comprehensive overview of global research. Longitudinal studies focusing on tracking changes over time would be instrumental in identifying emerging trends and shifts in research focus, thereby capturing the rapidly evolving nature and applications of XR technologies. The influence of geographical proximity on citation behavior has been documented (Abramo et al., 2020), suggesting that it significantly affects citation dynamics. An in-depth exploration of the geographical and institutional diversity of XR research could shed light on the drivers of research concentration in certain areas and inform strategies to foster a more inclusive and globally representative research landscape.

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