Original Paper

A Visualized and Bibliometric Analysis of Information-related Research on COVID-19

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Abstract

When a public health crisis occurs, people's needs for information increase sharply and information access can be a matter of life and death. To understand citizens' information-related behavior under COVID-19, information researchers published prolifically. The present study aims to map the contour of COVID-19 researches relating to information. Publications relating to information issues during COVID-19 pandemic were retrieved from the Web of Science Core Collection. Using the Citespace bibliometric tool, most productive authors, journals, institutions, countries and most cited articles were identified. Keyword co-occurrence and cluster analysis were conducted to reveal dominant topics and research trends. The 511 articles meeting the filter criteria were published by authors from a total of 66 countries. The United States contributed 190 articles, ranking first globally. Dominant topics included the role of technology, crisis communication, COVID-19 information management, information literacy and misinformation on social media. But scant attention was directed to the role of individuals situated in the middle of information flows, to the informational relevance of personal narratives circulating through social media and to country- or disaster-based comparative studies. Researchers can also observe whether COVID-19-driven informational interventions continue as standard practice after the pandemic ends.

Keywords

information, COVID-19, Citespace, bibliometric analysis

1. Introduction

The 2019 novel coronavirus disease has exerted a profound impact globally. On 30 January 2020, WHO declared it a public health emergency of international concern and a pandemic on 11 March 2020. To effectively mitigate the pandemic, keeping citizens well informed became a matter of first

importance (He, Zhang, & Li, 2021). When a public health crisis happens, people's needs for information increase sharply and information access can be a matter of life and death, which is especially true with a pandemic of such magnitude and fatality as COVID-19 (Naeem & Bhatti, 2020). Citizens wanted to know how to protect themselves and where to seek help when necessary; policy makers needed to be well-informed about how the pandemic was developing so as to take more targeted and effective anti-epidemic measures. There was also the problem of unequal information access. While some demographic groups, such as the old, the disabled and those who spoke minority languages, stayed under-informed owing to the difficulty they encountered while seeking information, some others were at a loss what information source to believe when bombarded with too much information (Zarocostas, 2020). Therefore, the information-related research can be of significant value in helping contain the on-going pandemic and the like in the future. To understand citizens' information-related behavior under COVID-19, information researchers, among others, were quick to contribute their share. Publications approaching COVID-19 pandemic from the perspective of information have increased steadily since its very onset and have reached a considerable size.

Bibliometric study proves an effective way to get a clear picture of a research field (McBurney & Novak, 2002). It can provide a comprehensive view of extant studies in a given field, identifying dominant topics and trends and guiding the future research. But so far, to the best of our knowledge, there remains a dearth of studies to map the information-related publications on COVID-19. To fill this gap, the present study, using the Citespace bibliometric tool and based on the Web of Science Core Collection, aims to map the contour of COVID-19 researches relating to information. To be specific, this study hopes to find answers to the following questions:

Question 1: which authors, journals, institutions and countries published most to address information issues arising from COVID-19?

Question 2: what were the dominant topics and significant findings of the extant information-related research on COVID-19?

Question 3: what gaps remain in information-related research on COVID-19 and what implications can be drawn for future studies?

2. Materials and Methods

2.1 Data Collection

We searched the Web of Science Core Collection in the category of "Information Science Library Science" using the keywords: TS=("COVID" or "COVID-19" or SARS-CoV-2 or "novel coronavirus" or "coronavirus disease 2019") and TS=("information" or "informational" or "inform" or "informed" or "informing" or "misinformation" or "disinformation" or "information access" or "information seeking"). Time span is from 2020 to 2022 and the document type is confined to articles and reviews. Only publications in English were collected. The search was conducted on 6 December 2022 and a total of 529 articles and reviews meeting the filter criteria were obtained. The author manually excluded a

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few unrelated documents and some duplicates were also removed using the Citespace, which left the final documents for analysis at 511.

2.2 Bibliometric Analysis

In this study, Citespace 6.1 R2, developed by Chen (2004), was chosen as the tool to analyze downloaded documents. When exporting files from Web of Science Core Collection, we opted for "full records and cited references". The downloaded files were then put into Citespace to identify countries, institutions and journals that contributed most, before which time slicing, duplicate removing, pruning and other necessary procedures were completed. With that, we conducted analyses of document co-citation, keyword co-occurrence and clustering, the results of which were visualized. Through document co-citation analysis, we detected important documents and relationships between them. The keyword co-occurrence analysis was carried out to get some insights into the knowledge structure of COVID-19-related information research field, while cluster analysis was done to further group the collected data.

3. Findings and Discussion

3.1 Countries and Institutions

The 511 articles were globally published by authors from a total of 66 countries. As can be seen in Table 1, the 10 most productive countries account for more than 90% of the total. The United States contributed 190 articles, far exceeding any other countries. China ranked second with 89 publications, followed by England (47/511), Spain (36/511) and Australia (31/511).

The Table 2 presents the top 10 most productive institutions. The University of London produced 17 publications, making it the most prolific institution. The State University System of Florida and University of Texas System produced 13 publications each, followed by Pennsylvania Commonwealth System of Higher Education with 11 publications and the University System of Georgia with 10 publications. Among the top 10 prolific institutions, 7 are from the United States.

Table 1. Top 10 most Prolific Countries for Information-related Research on COVID-19

Rank	Countries	Publications (511, %)	Rank	Countries	Publications (511, %)
1	USA	190(37.2)	6	India	22(4.3)
2	China	89(17.4)	7	South Korea	19(3.8)
3	England	47(9.2)	8	Pakistan	17(3.3)
4	Spain	36(7.0)	9	Germany	15(2.9)
5	Australia	31(6.1)	10	Canada	15(2.9)

Table 2. Top 10 most Prolific Institutions for Information-related Research on COVID-19

Rank	Institution	Publication	Rank	Institution	Publication
1	University of London	17	6	University of North Carolina	9
2	State University System of Florida	13	7	University of Punjab	9
3	University of Texas System	13	8	California State University System	8
4	Pennsylvania Commonwealth System of Higher Education	11	9	City University of Hong Kong	8
5	University System of Georgia	10	10	Harvard University	8

3.2 Journals and Authors

Presented in Table 3 is the list of top 10 contributing journals. The "Journal of the American Medical Informatics Association" ranked first with 50 publications and was followed by "Journal of Health Communication" with 34 publications, which is understandable considering that both of them focus on health information issues. Another finding is that of the top 10 journals, those concerned with information issues in general, such as "International Journal of Information Management", "Information Processing Management", "Profesional De La Informacion" and "European Journal of Information Systems", account for close to 20% of the information-related research on COVID-19. Also noteworthy is that 4 of the top 10 journals belong to the category of telecommunication and technology, namely "Online Information Review", "Library Hi Tech", "Telematics and Informatics" and "Information Technology People". This is probably due to the fact that during the pandemic, frequent lockdowns and restrictions on movement increased the use of information technologies to communicate or to stay connected.

The 511 articles analyzed in this study were written by a total of 332 scholars, of whom professor Khalid Mahmood, Director of the Institute of information management at the University of Punjab, topped the author list with 5 publications, followed by Annemaree Lloyd, Alison Hicks and Reijo Savolainen with 4 publications each.

Table 3. Top 10 most Prolific Journals for Information-related Research on COVID-19

Rank	Journal	*N*(511, %)
1	Journal of the American Medical Informatics Association	50(9.8)
2	Journal of Health Communication	34(6.7)
3	International Journal of Information Management	31(6.1)
4	Information Processing Management	29(5.7)
5	Online Information Review	29(5.7)

6	Library Hi Tech	28(5.5)
7	Profesional De La Informacion	22(4.3)
8	Telematics and Informatics	20(3.9)
9	European Journal of Information Systems	17(3.3)
10	Information Technology People	17(3.3)

3.3 Most Cited Articles

In Table 4, we present the 10 most cited articles dealing with COVID-19 information issues. Ranking at the top is "Impact of COVID-19 pandemic on information management research and practice: Transforming education, work and life", which received 245 citations though published in December 2020. From the second to the fourth place are "Impact of Covid-19 on the media system", "Communicative and democratic consequences of news consumption during the outbreak", "Fake news and COVID-19: modelling the predictors of fake news sharing among social media users" and "Digital transformation of everyday life - How COVID-19 pandemic transformed the basic education of the young generation and why information management research should care?", each receiving more than 200 citations. Of note is that the top 10 highly cited articles were all published from the year 2020 through 2021 and 6 of them were published in "International Journal of Information Management".

Table 4. Top 10 most-cited Articles Contributing to COVID-19 Information Research

Citations	Title	Author(time)	Journal
245	Impact of COVID-19 pandemic on information management research and practice: Transforming education, work and life	Dwivedi et al. (2020.12)	International Journal of Information Management
207	Impact of Covid-19 on the media system. Communicative and democratic consequences of news consumption during the outbreak	Casero-Ripolles et al. (2020.3)	Profesional De La información
205	Fake news and COVID-19: modelling the predictors of fake news sharing among social media users	Apuke and Omar (2021.1)	Telematics and Informatics
204	Digital transformation of everyday life - How COVID-19 pandemic transformed the basic education of the young generation and why information management research should care?	Iivari et al. (2020.12)	International Journal of Information Management
176	What drives unverified information sharing and cyberchondria during the COVID-19 pandemic?	Laato et al. (2020.5)	European Journal of Information Systems
164	The use of digital technologies by small and medium enterprises during COVID-19: Implications for theory and practice	Papadopoulos et al. (2020.12)	International Journal of Information Management

162	Business models shifts: Impact of Covid-19	Seetharaman (2020.10)	International Journal of Information Management
116	Inside out and outside in: How the COVID-19 pandemic affects self-disclosure on social media	Nabity-Grover et al. (2020.12)	International Journal of Information Management
107	Agile and adaptive governance in crisis response: Lessons from the COVID-19 pandemic	Janssen and van der Voort (2020.12)	International Journal of Information Management
105	An exploration of how fake news is taking over social media and putting public health at risk	Bin et al. (2021.6)	Health Information and Libraries Journal

3.4 Co-citation of Documents

The results of document co-citation mapping, setting a threshold of 3, are illustrated in Figure 1. The 10 most co-cited articles are shown in Table 5. 3 of the top10 co-cited articles were published before the present pandemic broke out, and 7 of the top 10 co-cited articles, though departing from different angles, focused on fake news or misinformation. It can thus be concluded that misinformation constituted one of the most explored topics. This finding comes as no surprise, because with the number of social media users continuing to rise and people getting increasingly dependent on social media for information, the problem of misinformation became too big to ignore even before COVID-19 and was only made to loom still larger by it. As WHO Director General Tedros Adhanom Ghebreyesus put it, "We're not just fighting an epidemic; we're fighting an infodemic" (WHO, 2020).

Specifically, the most co-cited article (*n*=9) was a report by Zarocostas (2020), in which he introduced several endeavors that WHO had developed to address the problem of infodemic and improve people's access to quality information relating to COVID-19. Among the endeavors were launching a new information platform aimed to provide targeted populations with tailored information, designing tools to direct people to reliable sources when they were searching for information on social media using terms such as "COVID" or "corona-virus", increasing the role of traditional mass media and working together with UNICEF, International Federation of Red Cross and other agencies having experiences in risk communications. The second and third most co-cited article (*n*=5) were written by Laato S. and Khan M. respectively. Laato et al. (2020) developed and tested a research model to find out what factors motivated people to share COVID-19 information without verifying its truthfulness. The findings showed that two strong predictors were information overload and trust in online information; women were found more vulnerable to cyberchondria while men were more likely to share unverified information. The qualitative study by Khan et al. (2019) identified another important factor that drove unverified information sharing: the perceived ability to recognize false information on social media. As to solutions, both studies emphasized the role of individuals, recommending that people be a responsible media gatekeepers, be healthily skeptical of news and try not to be overloaded with information.
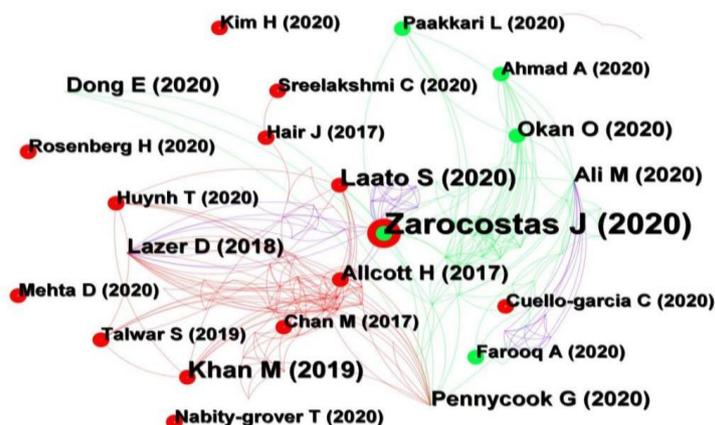
Figure 1. Co-citation Network for Information-related Documents on COVID-19

Table 5. Top 10 most Co-cited Articles Contributing to COVID-19 Information Research

Citations	Year	Author	Title
9	2020	Zarocostas J	How to fight an infodemic.
5	2020	Laato S	What drives unverified information sharing and cyberchondria during the COVID-19 pandemic?
5	2019	Khan M	Recognise misinformation and verify before sharing: a reasoned action and information literacy perspective.
4	2018	Lazer D	The science of fake news.
4	2020	Dong E	An interactive web-based dashboard to track COVID-19 in real time.
4	2020	Okan O	Coronavirus-Related Health Literacy: A Cross-Sectional Study in Adults during the COVID-19 Infodemic in Germany.
4	2020	Pennycook G	Fighting COVID-19 Misinformation on Social Media: Experimental Evidence for a Scalable Accuracy-Nudge Intervention.
4	2017	Allcott H	Social Media and Fake News in the 2016 Election.
4	2020	Ali M	The COVID-19 (Coronavirus) Pandemic: Reflections on the Roles of Librarians and Information Professionals.
3	2020	Kim H	Effects of COVID-19 Misinformation on Information Seeking, Avoidance, and Processing: A Multicountry Comparative Study.

3.5 Co-word/Cluster Analysis

Keywords can give us some clues as to the subject matter and main content of an article. Often, if two or more keywords occur in the same article, it means that they are closely related. The relatedness between two terms is generally positively associated with the frequency of co-occurring. The more frequently a keyword co-occurs in articles, the more significant it is. Therefore, a keyword co-occurrence analysis can help identify dominant topics of a given field. The top 10 co-occurring

keywords were social media, information, impact, model, information technology, communication, technology, knowledge, fake news and health. The network of co-occurring keywords is shown in Figure 2, and the keywords with frequencies of more than twenty are displayed in Table 6.

On the basis of the results of keyword co-occurrence analysis, a cluster analysis was conducted. The 11 most significant clusters are shown in Figure 3 and list of clusters are presented in Table 7. As is obvious, some clusters overlap one another, which indicates that the publications under the overlapping clusters share to varying degrees some concepts, topics or data (Chen, 2006). In what follows, we interpret the clusters by grouping the closely related ones around relevant themes.

Table 6. The Co-occurring Keywords of High Frequency

Rank	Keywords	Count	Rank	Keywords	Count
1	social media	97	11	management	24
2	information	67	12	media	24
3	impact	45	13	trust	23
4	model	38	14	behavior	22
5	information technology	36	15	information literacy	22
6	communication	35	16	covid-19 pandemic	22
7	technology	30	17	academic library	21
8	knowledge	29	18	acceptance	21
9	fake news	29	19	adoption	20
10	health	27	20	perception	20
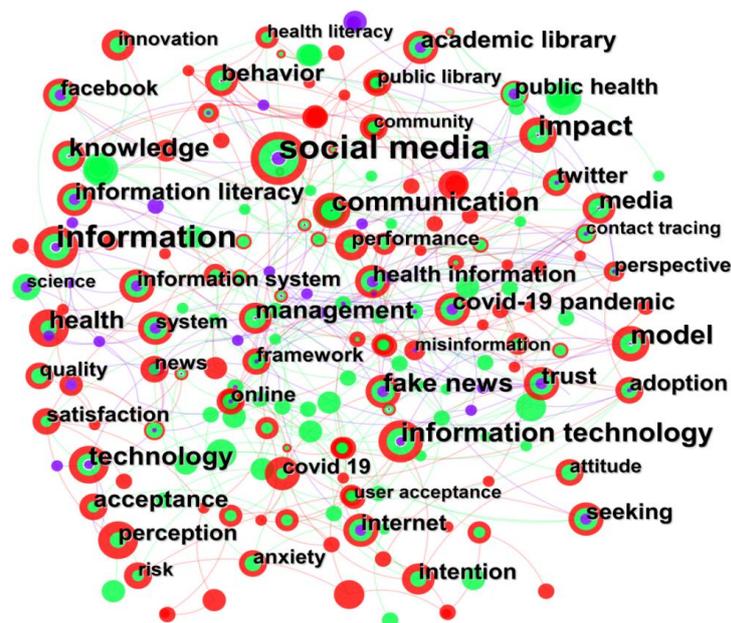
Figure 2. Keyword Co-occurrence Network for Information-related Documents on COVID-19

Theme 1: The Role of Information Technology

The theme of "The Role of Information Technology" emerges from cluster #0 "technology adoption" and cluster #10 "information literacy". As a result of lock-downs, social distancing, contactless services and other inconveniences caused by COVID-19, the global efforts to mitigate the pandemic were characterized by increased use of various information technologies. Video conferencing platforms made online education possible during lock-downs (Nadire & Daniel, 2021); machine translation technologies facilitated communication between doctors and cases that spoke different languages; Big Data Analytics was employed to alert people to high-risk areas; health QR code informed people of their health status in real time (Mingis, 2020), to name just a few. The fact that information technologies find extensive use in building resilience and helping people cope with the "new normal" provides multiple opportunities to study the role of information technologies in times of crisis. A considerable number of publications exist that examine and evaluate the role of information technologies (Kaplan, 2020). Overall, information technologies are believed to have given a satisfactory performance in the fight against the global pandemic.

The increased use of information technologies during the pandemic required individuals to be adequately information literate in order to wisely and critically navigate the sea of information. Being information literate means having the ability to recognize information need, to access, evaluate, effectively use and manage information (Stern & Kaur, 2010). But owing to the increasingly important role of technology in disseminating and accessing information, information literacy has almost become synonymous with ICT (Information and Communications Technology) literacy. Indeed, the very advent of the concept "information literacy" is believed to be highly attributable to technology-driven information explosion (Grafstein, 2007). It was revealed that information literacy helped curtail the spread of COVID-19 misinformation (Igbinovia, Okuonghae, & Adebayo, 2021). Moreover, how well a country as a whole is equipped with information technology can also be a determinant of people's information seeking performance (Kassie et al., 2022).

Theme 2: The Role of Social Media

The theme of "The Role of Social Media" emerges from cluster #3 "social media", cluster #4 "social network analysis" and cluster #5 "health literacy". The formation of Cluster #4 "social network analysis" can be explained by the fact that many studies about social media adopt the method of social network analysis. An overview of the literature focusing on the role of social media revealed that the following topics attracted most attention.

First, patterns of information spreading on social media during the pandemic. Understanding how information spreads on social media can help inform risk communication strategies. Kothari et al. (2022) conducted a social network analysis in order to find who influential information senders were and what type of information received more attention. The results showed that in COVID-19-related social network, although health experts were among most influential information disseminators on social media, but information from these professionals was less retweeted when compared with

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celebrities and public figures like Trump, a finding confirmed in a study by Brennen et al. (2020). Information expressing opinions or sharing experiences with COVID-19 was retweeted by social media users more than health-related professional knowledge and other kinds of information. A study by Su et al. (2021) demonstrated that compared with pre-COVID-19 period, media didn't change much in deciding what to report. In other words, sensational news are favored over vital but less eye-catchy information. Moreover, as the pandemic developed, there occurred a shift of focus on the part of social media users. Initially, they were attentive to the situation of the original epidemic center (namely Wuhan, China), to global cases and to the nature of the new virus. Later, their focus shifted to preventive measures, safety guidelines and pandemic mitigation policies (Xing et al., 2022). Differences were also observed in COVID-19 information networks of different racial/ethnic groups. Based on a social network analysis of Twitter, Yum (2022) found that for Whites, news media, politicians, and researchers acted as key players (namely the individuals or agencies that are more mentioned or depended on for information by Twitter users); both Asians and blacks had news media as their key players; for Hispanics, key players were mostly institutes.

Second, the role and efficacy of social media in crisis communication initiated by government agencies. The ubiquity of social media allows information to reach a wide audience at a high speed. Therefore, recent years have witnessed increased use of social media (such as Twitter and Wechcat) by government agencies to communicate with the public and even more so during the pandemic. Many studies examined the way government agencies used social media to engage the public in the response to COVID-19. Zhu et al. (2022) evaluated the Government-public interconnectivity during the pandemic and found that social media could be efficiently leveraged to not only disseminate information but also solicit feedbacks. The practical implication is that social media can function as a platform for dialogue between Government and the public so that the former can get better understand peoples' needs and initiate timely response. Different from previous studies conducted under normal circumstances, media richness was found to negatively impact citizens' engagement with government social media in uncertainty-fraught situations like COVID-19 pandemic. It followed that citizens were more concerned with the textual content of a post and whether a picture or video was added made little difference. During the early stage of the pandemic, a large proportion of information from government social was alarming messages, probably aimed to heighten people's awareness of the pandemic. During the following months, the percentage of reassuring messages steadily increased, which was critical for reducing fear and panic (Rao et al., 2020).

Third, the proliferation of dis/misinformation on social media. Not long after the breakout of COVID-19 pandemic, false information and conspiracy theories surrounding the origin of the virus went viral on social media. Later on, misinformation multiplied in both the volume and the kind. Rumors made the rounds on social media that 5G technology was linked with the virus, that masks were used to collect personal data, that a cure was found in some place, that the pandemic was a hoax designed to make money and that another lockdown would be imposed and you needed to increase the

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stock of life necessities (Satariano & Alba, 2020). The danger with misinformation during a pandemic is that it may influence people's judgement and cause them to make wrong decisions, mostly not without consequences. Importantly, the prevalence of misinformation on social media may impede the efforts to control the pandemic. For example, it was observed that an infodemic could lead individuals to be cynical about information from established sources and meaningfully wide consensus was hard to reach, the result of which was less willingness to act on official guidelines (Espina & Spracklin, 2022). Groundless claims, conspiracy theories and pseudo-scientific claims were identified as three common types of false information (Naeem, Bhatti, & Khan, 2021). A research by Apuke and Omar (2021) revealed that altruism was the most significant predictor of sharing misinformation. Other predictors included socializing needs, passing time and seeking information. No strong correlation was found between entertainment purposes and misinformation sharing. To combat health-related misinformation, suggested solutions included medical experts sharing accurate and science-based information on social media more frequently, social media users critically appraising and cross-checking information before sharing and social media platforms putting more efforts into fact-checking.

Finally, health literacy and online information consuming. During the pandemic, people spent more time than before searching online for health-related information and more health-related information was shared and reshared on social media. If aforementioned information literacy determines whether one can locate the needed information, health literacy, defined as "competencies of accessing, understanding, appraising and applying health-related information" (Sørensen et al., 2012), determines whether one can correctly consume the health-related information obtained. Also, high health literacy can help reduce fear and anxiety (Nguyen et al., 2020). Abdoh (2022) found that most undergraduates (72.2%) were able to obtain the exact information they needed, but they faced difficulty in determining relevance and only about one third of them could apply the information in daily life. Similar findings emerged from a study conducted in Ghana, where respondents reported a low skill in differentiating scientific from unscientific information (Abdulai et al., 2021). College students generally reported a high level of health literacy, but the overabundance of (mis)information subjected them to self-doubt, and information providers (social media in particular) were called on to offer tools enabling information consumers to evaluate messengers' trustworthiness (Rosário et al., 2020).

Theme 3: COVID-19 Information Management

The theme of "COVID-19 Information Management" emerges from cluster #1 "crisis communication", cluster #2 "belief", cluster #7 "information system" and cluster #8 "knowledge management". Specifically, publications under this theme are mostly trying to answer the following two questions: 1) how should crisis information be communicated to the public; 2) how can COVID-19 information be managed and shared efficiently among medical professionals, policymakers and general practitioners so that it can be put to optimal use in helping fight the pandemic.

Crisis communication is defined as "the collection, processing, and dissemination of information required to address a crisis situation" (Coombs, 2010). During such public health emergencies as the

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COVID-19, it is of paramount importance to communicate quality information to the public in a timely manner, which can help people make informed decisions and thus reduce loss of life. Top-down communication (initiated by governmental agencies and/or heath institutions) proved short of expectations, as a result of the delay in reaching target groups, the supply-and-demand mismatch, and most importantly, the limited availability of important information in minority languages. Fortunately, where top-down communication failed to deliver, the bottom-up approaches (initiated by non-governmental organizations or individuals) could help fill the gap to some degrees (Zachariah et al., 2022). Another problem with top-down approach concerned people of great influence. As it happened during COVID-19 pandemic, some politicians put political agendas before urgent fact-based information, conveying, purposely or inadvertently, conflicting and even wrong messages (Tian & Yang, 2022).

In addition to the provision of information, problems also arose on the receiving end of crisis communication. Several demographic groups encountered great difficulty in this regard. Some rural dwellers heavily relied on traditional media like town crier as their major information source, but it was less used today, being gradually replaced by digital media (Abaneme et al., 2021). Immigrant, forced immigrants in particular, had limited proficiency in languages of new destinations. Because of the shortage of sign language interpretation services and with not much information available in preferred sign language, deaf or hearing-impaired people had a hard time keeping up-to-date with the pandemic (Mathews et al., 2022).

For mitigation measures to be effective, accurate and up-to-date COVID-19 information need to be readily accessible for public health responders from different fields. Information about the virus itself can assist in developing vaccines, making drugs and finding new treatment methods. Information about how the pandemic develops and impacts locally or globally can help develop better anti-pandemic intervention strategies. To meet the need, many countries have developed COVID-19 dashboards to make available the real-time information (Field et al., 2021). Also, as introduced by Garcia et al. (2020), CDC COVID-19 Information Management Repository, a publicly available information management tool, achieved applaudable progress in improving data interoperability and availability by engaging data standards developers, implementors, and users as well. Despite these efforts, problems remain in the current COVID-19 data sharing systems, including data decentralization, inconsistencies, security and legal issues, limited financial support (Gao et al., 2020).

Theme 4 Citizens' Attitude Towards Contact-tracing APPs

The theme of "Citizens' Attitude Towards Contact-tracing APPs" emerges from cluster #6 "perception" and cluster #9 "contact tracing". Contact tracing apps proved effective in identifying the transmission trajectory of the coronavirus and users did perceive their benefits and usefulness (Ferretti et al., 2020). Despite that, contact-tracing apps inevitably raised some concerns, the most common and worrisome of which was users' fear that they would come under unauthorized surveillance and their private information might be disclosed and misused (Trang et al., 2020). People were constantly caught in the

dilemma of accepting the tracing apps to serve the public good or rejecting it in order to protect personal privacy (Rowe, 2020). Besides, it is found that in order for tracing apps to produce satisfactory effect, no less than 60% smartphone users needed to install them (Cho, Ippolito & Yu, 2020). But controversies surrounding such apps negatively impacted user adoption and technology diffusion (Hassandoust, Akhlaghpour, & Johnston, 2021). Advocacy campaigns alone may not be adequate to ensuring mass adoption. Instead, some scholars hold that to enhance user trust and ultimately peoples' willingness to cooperate, technological specifications or legal actions were necessary to make people assured that the personal data collected were well protected against misuse and were not more than necessary to perform mitigation tasks.
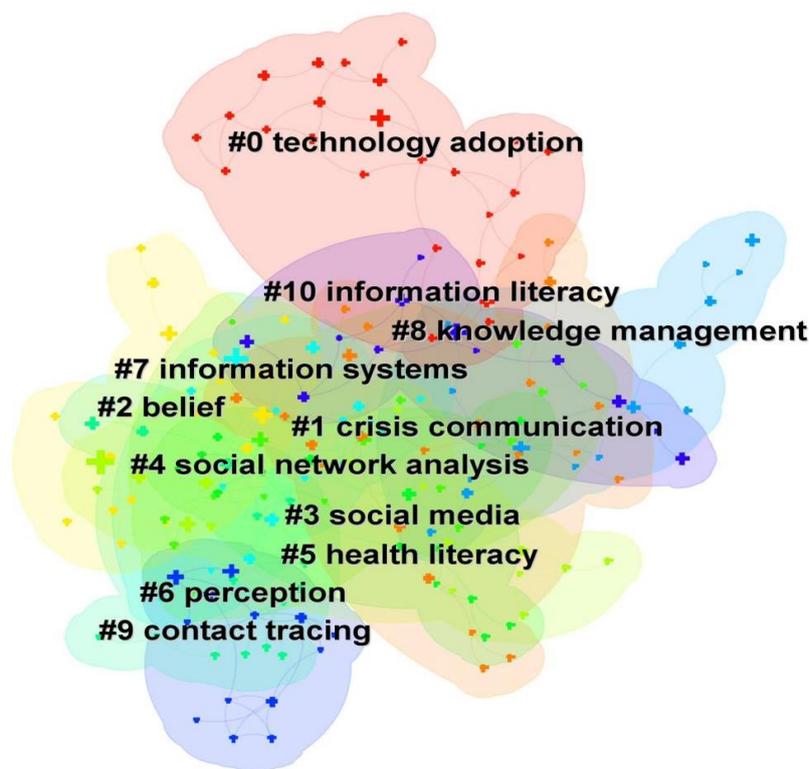
Figure 3. Clusters Based on Keyword Co-occurrence

Table 7. Keyword Clusters of Information-related Documents on COVID-19

Cluster ID	Size	Silhouette	Cluster names	Top Terms (log-likelihood ratio, p-level)	Terms (mutual information)
0	25	0.91	technology adoption	technology adoption (11.2, 0.001); utaut2 (10.35, 0.005); protection motivation theory (10.35, 0.005); perceived severity (10.35, 0.005); self efficacy (6.68, 0.01)	is use (0.31); delone and mclean is model (0.31); knowledge-sharing behavior (0.31); college student (0.31); covid-19 health anxiety (0.31)

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1	23	0.922	crisis communication	crisis communication (10.67, 0.005); deep learning (9.83, 0.005); aspect-based sentiment analysis (9.83, 0.005); public opinion (9.83, 0.005); pandemics (7.98, 0.005)	debunking (0.36); fundamental causes theory (0.36); recovery policies (0.36); retweeting (0.36); strategic communication (0.36)
2	18	0.934	belief	belief (6.07, 0.05); survey (5.55, 0.05); work communication (4.57, 0.05); perceived vaccine efficacy (4.57, 0.05); online news use (4.57, 0.05)	work communication (0.44); perceived vaccine efficacy (0.44); online news use (0.44); individual job performance (0.44); big five (0.44)
3	17	0.886	social media	social media (22.32, 1.0E-4); health communication (13.54, 0.001); fake news (8.58, 0.005); 0 (8.54, 0.005); social media users (8.54, 0.005)	affective authority (0.53); cognitive authority (0.53); theory of planned behavior (0.53); analytics (0.53); health (mis)information (0.53)
4	17	0.875	social network analysis	social network analysis (10.83, 0.005); misinformation (8.15, 0.005); fake news (7.51, 0.01); dr fauci emails (5.76, 0.05); echo chamber (5.76, 0.05)	dr fauci emails (0.21); echo chamber (0.21); text mining (0.21); word cloud (0.21); information ethics (0.21)
5	16	0.975	health literacy	health literacy (21.8, 1.0E-4); public health (19.69, 1.0E-4); research (19.03, 1.0E-4); quantitative (17.92, 1.0E-4); consumer health information (11.93, 0.001)	internet access (0.19); dissemination of information (0.19); topic modeling (0.19); social q&a (0.19); academic (0.19)
6	16	0.86	perception	perception (11.21, 0.001); predictor (11.21, 0.001); information avoidance (10.74, 0.005); model (7.78, 0.01); internet public opinion (7.52, 0.01)	grounded theory (0.23); cognitive dissonance (0.23); public health emergencies (0.23); message (0.23); computer-supported collaborative work (cscw) (0.23)
7	16	0.885	information systems	information systems (9.67, 0.005); gerfalk (9.3, 0.005); online learning (6.26, 0.05); covid-19 crisis (5.69, 0.05); digital divide	sociomaterial construction (0.42); correction action (0.42); hinari (0.42); governmental restrictions (0.42); outbreak

				(5.69, 0.05)	(0.42)
8	15	0.782	knowledge management	knowledge management (9.71, 0.005); e-government (8.26, 0.005); social media (8.03, 0.005); digitalization (7.08, 0.01); probit estimations (5.37, 0.05)	probit estimations (0.27); digital contact-tracing app (0.27); empirical research (0.27); guideline (0.27); spatial econometrics (0.27)
9	13	0.941	contact tracing	contact tracing (7.52, 0.01); privacy calculus (5.81, 0.05); management (5.81, 0.05); media consumption (5.81, 0.05); cultural characteristic (4.71, 0.05)	cultural characteristic (0.41); hiv/aid (0.41); ethics (0.41); par angstrom gerfalk (0.41); clinical operations (0.41)
10	12	0.912	information literacy	information literacy (20.96, 1.0E-4); academic libraries (15.25, 1.0E-4); teachers (9.26, 0.005); behavior (7.59, 0.01); covid-19 pandemic (7.53, 0.01)	extrinsic factor (0.43); rhetorical strategies (0.43); loss framed message (0.43); coping (0.43); online civic behavior (0.43)

4. Implications for Future Studies

This bibliometric study found that the existing COVID-19-related research on information covered a wide range of areas and profound theoretical and practical implications have been drawn with regard to technology adoption, social media, fake news and risk communication. Still, some topics that are no less important remain underexplored and implications for future studies can accordingly be outlined as follows.

First, more scholarly attention should go to those who are positioned in the middle of information flows, such as telephone operators and community workers. Studies abound that focus on the original sources and the ultimate recipients of information. But it is not uncommon that before reaching target groups, information is reworked by those in between. For example, from our own experience, when people got cynical towards official or established information channels, information concerning mitigation policies or guidelines would not be directly communicated to residents. Instead, such information was first sent to community workers, who then reworked it before sending it to residents. The role of community workers as a information mediator is important in that the rapport and amity established between community workers and residents through daily interactions can help reduce residents' resistance against official guidelines and boost their willingness to conform. Researches involving "information mediators" will surely give us a more nuanced understanding of how risk communication actually works.

Second, more comparative studies of risk communication should be conducted. The comparison can be both temporal and spatial. Temporally, information accessibility and patterns of information seeking

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during different kinds of public health crises can be compared so as to identify lessons learned and gaps to be filled. Spatially, because of differences in internet access, religious belief, culture and previous experiences with disasters, countries may widely differ in ways of keeping their citizens informed, which apparently calls for country-based comparative studies.

Third, the role of personal narratives as a information source should not be undervalued or simply dismissed. Being oftentimes emotive and affective, personal narratives, with all their idiosyncrasy, have a role to play in communicating about a risky situation. A case in point is that as Chinese people got increasingly ambivalent about zero-COVID policy, they looked abroad to form their own judgement about the global pandemic. Catering to that need, numerous overseas Chinese bloggers on Douyin (Chinese equivalent of Tiktok) shared their personal experiences with COVID-19 infection and described how a foreign country performed when restrictions there were lifted. The problem was that these bloggers sometimes painted totally different pandemic pictures of the same country or even the same city. Therefore, there is the danger of people being wrongly informed about the pandemic abroad.

Finally, with the end of the pandemic in sight, future studies can observe the long-term impact of COVID-19 on information-related practice. Topics worth investigating include--but certainly not limited to--what COVID-19-related informational practice, if any, continues well into post-COVID era; whether any information technology application transitions from an emergency response to a practice of norm; how COVID-19 changes information literacy training; what changes result from experiences with the pandemic in terms of information accessibility, information legislation, information management and citizens' concerns about the privacy of personal information.

5. Limitations

First, the present study inevitably suffered from the fact that it was limited to documents collected from Web of Science Core Collection and other databases were not included. Second, only articles in the English language were chosen for analysis. Though English remains the dominant language in global academia, information-related quality researches in other languages were undoubtedly numerous as well, but were not covered in this study. Third, as we conducted the study, more publications relevant to our topic were coming out. Therefore, findings from our study were valid only within a certain time frame and to be more comprehensive, further such researches are needed.

6. Conclusions

The fight against COVID-19 pandemic is a matter of, among other things, information. To be truly "all in this together", a successful and inclusive response to the pandemic necessitates heightened information sensitivity, so that information is communicated in ways conducive to crisis management and all demographic groups stay well informed. To evaluate the efficacy of COVID-19-related communication, understand people's information seeking or consuming behavior and identify possible information gaps, information researchers have published prolifically. In order to delineate

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information-related research on COVID-19, the present study conducted *via* Citespace a bibliometric and visualized analysis of publications collected from the Web of Science Core Collection. The United States contributed 190 articles, ranking first globally. "Journal of the American Medical Informatics Association" was the most productive journal with 50 publications. Keyword co-occurrence and cluster analyses revealed that dominant topics included the role of technology in providing and accessing information, crisis communication, COVID-19 information management, information literacy, the spread of misinformation on social media, contact-tracing apps and people's mixed perceptions. Based on findings in preceding sections, the current study finally drew some implications for future research. Specifically, more scholarly attention needs to be directed to the role of individuals situated in the middle of information flows, to the informational relevance of personal narratives circulating through social media and to country- or disaster-based comparative studies. Researchers can also observe the continuation (or lack thereof) of COVID-19-driven informational interventions after the pandemic ends.

Funding

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