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Article

How Do Multiple Actors Conduct Science Communication About Omicron on Weibo: A Mixed-Method Study

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Abstract
This article explores science communication about Omicron on Weibo by eight actors from November 2021 to June 2022. Regarding the themes of vaccines, symptoms, and medicines, we examined the actors' communication with content analysis, presented the interactions of different actors using social network analysis, and assessed the impact of weibos on public sentiment using SnowNLP and descriptive statistics. The results showed that scientists are still the most important actors, focusing on science issues and using contrasting and contextual frames. Central-level media play an essential mediating role, relaying scientific knowledge. Science communication on Weibo had a positive impact on public sentiment.

Keywords
Covid-19; Omicron; public sentiment; science communication; social media; sentiment analysis; Weibo

Issue
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1. Introduction

Social media provides a channel for the public to "participate in science" (Schäfer et al., 2018), and scientists are no longer the only actors in science communication. As one of China's largest social media platforms, Weibo is an essential channel for obtaining information, communicating and interacting, and expressing ideas ("Weibo Q1 profit tops estimates," 2022). Although the state still sets boundaries for what may be criticized, and the censorship is very effective in some instances, Weibo communication fulfills some of the core criteria of a public sphere, such as it having open debates about issues of common concern, continuous debates, and a large number of participants (Rauchfleisch & Schäfer, 2015).

The Covid-19 pandemic has created a global health crisis. Omicron (B.1.1.529), the fifth-generation variant of Covid-19, was first detected in South Africa on November 9, 2021, and classified as having a "very high" risk level on November 29 (World Health Organization, 2021). Omicron challenges the public's understanding of existing vaccines, medicines, and reagents, and targeted science popularization work is needed. China's zero-Covid policy stands out internationally and has been noted by the scientific community (Mallapaty, 2022). Therefore, promoting the public's timely understanding, rational knowledge, and scientific treatment of information related to Omicron is an important task in scientific communication. During the outbreak of Omicron, Weibo provides the possibility for public discussion of scientific issues and participation in science communication between all kinds of actors (Yi et al., 2022).

This article examined the science communication of different actors under different themes, the content, the interaction, and the effects of communication. The results can present the state of communication about Omicron on Chinese social media and provide lessons for science communication on similar topics.

2. Literature Review

2.1. Multi-Theme Communication on Weibo During the Covid-19 Pandemic

The internet has freed the public's imagination (Papacharissi, 2010). In the social media environment, the public is even considered to be formed, re-formed, and coordinated through a dynamic network of communication and social connections organized primarily around issues or events (Bruns & Burgess, 2015). In terms of China, as a virtual online platform, Weibo can quickly and inexpensively generate networks of public online issues that transcend geographical boundaries (Huang & Sun, 2014). Therefore, Weibo provides a platform for participation in public affairs and offers a channel for the Chinese public to express their opinions (Jiang, 2014). Since the outbreak of the Covid-19 pandemic, many studies have been conducted using the content and data disseminated on Weibo.

One kind focused on the impact of health information dissemination on Weibo on users' attitudes and behaviors. Some explored public opinions and attitudes towards the Covid-19 vaccine and their emotional orientations, which could result in increased preventive behaviors via dialogues on Weibo (Gao et al., 2021; Liu, 2020). Some investigated how communicating uncertainty about preliminary evidence affects the spread of inferred misinformation in a Weibo case study (Lu et al., 2021). Chen et al. (2021) concluded that geographical proximity and level of expertise influenced users' commenting behavior on the Covid-19 super theme on Weibo. Others conducted a correlation analysis between public attention level and Covid-19-related case numbers, topic themes analysis, and sentiment analysis (Hou et al., 2021; Tsao et al., 2021). Li et al. (2020) explored the developmental course of online public opinion in terms of fine-grained emotions presented during the Covid-19 epidemic in China. These studies, which follow the traditional focus of health communication research and inspire us to use these perspectives and methods of health communication in science communication about Omicron on Chinese social media, indicate that public mental health, emotional expression, and position in public health crises deserve attention.

Another strand of the literature analyzed the content of Weibo during the Covid-19 pandemic, discussing how topics and themes changed as the epidemic progressed and the changes in framing they reflected. Researchers revealed that the main topics of scientific communication revolve around the domestic epidemic, including Covid-19 drug treatments, vaccines, medical resources, patients' calls for help, the resumption of work and production (Wang et al., 2020), as well as the echo chamber effect of Weibo regarding Covid-19 information dissemination in several dimensions, including topics, interaction mechanisms, and interaction levels (Wang & Qian, 2021). Emotion and social network analyses were used to examine the emotion flow by comparing them with the information flow (Yi et al., 2022). Liao et al. (2020) revealed that the common content patterns identified in personal and government posts included sharing epidemic situations, general knowledge of the new disease, policies, guidelines, and official actions. In this study, we selected three related hot themes based on previous research and platform observation (Tsao et al., 2021; Wang et al., 2020): vaccines (prevention before infection), symptoms (of Omicron), and medicines (treatment after infection). According to the communication contents, the issues of the weibos in this study are divided into progress, politics, science, international situation, and risk (Hu et al., 2021).

Furthermore, frame refers to continuous cognitive, interpretive, and presentation patterns, including selection, emphasis, and exclusion (Gitlin, 2003). The technique of frame analysis, as the way to organize and present information about social issues and controversy, allows us to understand the nature and dynamics of popular sentiments on China's internet (Wang, 2013). This study uses four science communication frames to describe the writing logic of weibos' text: the contextual frame, the contrasting frame, the emphatic frame, and the declarative frame (Gao et al., 2021; Khoury et al., 2021).

2.2. Changing Actors on Science Communication and Active Actors on Weibo

After more than 30 years of development, science communication has had a series of achievements. Scholars have proposed three interaction models for science communication that can coexist as policy instruments: the deficit model, the dialogue model, and the participation model (Bucchi, 2008; Hetland, 2014; Trench, 2008). Considering the impact of scientific information on public decision-making, some scholars argued that in science communication, it is essential to recognize that there is a high degree of scientific uncertainty in many policy contexts (Rowe et al., 2005).

Therefore, an essential mission of contemporary science communication is building trust and dialogue between different groups and reconciling values. Scientific input to the policy process requires an "extended peer community" of all who have a stake in the dialogue on the issue (Funtowicz & Ravetz, 1993), and the public is equally qualified to dialogue with scientists on scientific issues of interest to them (Irwin & Wynne, 1996). As dialogue and participation are increasingly emphasized, more research has focused on the growing diversity of actors involved in science communication. Participatory communication theory suggests that communication should be a two-way process between producers and consumers of information (Servaes & Malikhao, 2005; Tufte & Mefalopulos, 2009). Therefore, the actors involved can be classified based on their engagement level, ability to contribute to scientific

knowledge, and relationship with other actors in the scientific community (Marent et al., 2012). Social network theory suggests that social networks influence communication patterns and behavior (Burt, 1995). In this theory, researchers usually classify actors according to their position in the network, level of influence, and relationship with other actors (Haythornthwaite, 1996). Actor-network theory suggests that actors are connected through networks of relationships that are both human and non-human, and that these networks shape social action and behavior (Latour, 2007; Law, 1992). This theory inspires us to classify actors based on their roles in shaping scientific knowledge and their relationships with other actors in scientific networks. All these theoretical doctrines provide the bases for classifying actors in this study.

Nowadays, the frequent scientific controversies have made various forms of public participation in science an inevitable choice for science communication activities in China (Jia & Liu, 2014). Scholars are paying more attention to the diversity of actors in different issues of Weibo science communication. Some classified the numerous users on Weibo into four primary groups: celebrities, organizations/media accounts, grassroots stars, and ordinary individuals (Guo et al., 2014). Many actors, such as governments, PR experts, universities and research institutions, science journalists, and bloggers, have been captured in science communication on Weibo (Weingart & Guenther, 2016). Ordinary citizens on Weibo constitute the largest category of initiators of online public opinion in China, but they have to rely on media outlets to spread the news of the case (Nip & Fu, 2016). Meanwhile, the Chinese government is also an active user of Weibo, utilizing the microblogging sphere better to understand public attitudes, concerns, and needs (Sullivan, 2014; Zhu et al., 2020). Zeng and Li (2020) stated that Chinese Center for Disease Control and Prevention increasingly uses social media to popularize daily health information and improve communication between the government and the public. All these studies showed the active communication activities of different actors in science communication on Weibo.

Synthesizing the above literature, essential actors in science communication include scientists, organizations, media, and the public. In this study, the actors are further refined and categorized according to their profession, status, background, and specific involvement in disseminating weibos about Omicron to develop a more comprehensive understanding of the dynamics of Weibo science communication.

2.3. Effects and Strategies of Science Communication on Weibo

Social media platforms are media-oriented in Chinese science communication and are key in mediating information dissemination (Chen et al., 2020). As mentioned, Weibo plays a significant role in daily and interpersonal communication among Chinese people during times of uncertainty and crisis. Weibo allows citizens to receive timely, fact-checked, and up-to-date science communication information from the government, scientists, and doctors. (Zhu et al., 2020). Therefore, the importance of Weibo demands that its effects and role in science communication be investigated. We still need to evaluate the science communication strategies of different actors on Weibo and find ways to improve communication effects on the various users on Weibo.

Research on the effects on science communication users on Weibo involves establishing relevant dimensions and indicators of effects evaluation. The evaluation of the effects focused on the impact on public sentiment. The emotional contagion hypothesis can explain the spreading and diffusion of emotions and the formation of large-scale emotional and cognitive contagion (Hatfield et al., 1993). Previous studies of public emotions during public health crises have found that people usually have negative emotions such as fear, anger, anxiety, disgust, and sadness (Yang & Chu, 2018). Emotionally charged Twitter messages are retweeted more rapidly and often than neutral ones (Yang et al., 2019). In addition, some scholars measured the influence of Weibo content by the number of likes, reposts, and comments on the message content (Ma & Liu, 2020). Research showed that reposting behavior can reflect a position of viewpoint agreement and a willingness to assist in the diffusion of information (Shan et al., 2017). Some authors extracted engagement data (likes, comments, shares, and followers) from government agency accounts regarding Covid-19 posts to assess online public engagement with government posts (Liao et al., 2020). Using the number of reposts and the emotional classification of comments has been the regular way to analyze the effects of science communication on Weibo (Liu, 2020; Yang et al., 2019). These studies inspired us to examine weibos' comment sentiment and repost numbers, thus generalizing science communication's impact on public sentiment.

Choosing appropriate communication strategies in science communication, especially the narrative style, is a major initiative to promote public sharing of science communication content on social media platforms and to take preventive measures (Ngai et al., 2020). One study systematically investigated how Chinese central government agencies used social media to promote citizen engagement during the Covid-19 crisis (Chen et al., 2020). Official health organizations, scientists, and physicians tended to adopt a more flexible communication strategy on social media (Che et al., 2022). Some argued that the revelation of personal preferences in the form of individualized expressions of opposition was more common than mobilization and coordination. Such preferences were legitimized by the personal frames of risk and the distrust in government (Huang & Sun, 2016). Another framework analysis of Weibo health information found that gain-framed messages

and statistical expressions can successfully improve the influence of messages (Rao et al., 2020). Zhang and Skoric (2020) focused on Chinese environmental science communication on Weibo and found that government-organized and grassroots NGOs differ significantly in their strategies. A study found that health influencers in China use low-fear appeal and high-efficacy messages to communicate with their followers (Zou et al., 2021). Therefore, the scientific communication strategies of different actors about Omicron are also one of the concerns of this study.

3. Study Aim and Research Questions

Taking science communication about Omicron activities on Weibo in China as the research object, this article aims to present and analyze the actors (who provide scientific information), contents (the issues, topic, frame, and position contained in samples), interactions (communication among the actors), and impact on public sentiment. It focuses on the performances of different actors in Weibo science communication and the changes and innovations brought by Weibo to science communication. The research questions are:

RQ1: Who are the main actors in science communication about Omicron on Weibo?

RQ2: What are the contents of science communication about Omicron?

RQ3: How do the actors of science communication about Omicron interact with each other?

RQ4: What is the impact of science communication about Omicron on public sentiment?

4. Methodology

4.1. Method

Omicron has sparked an ongoing and complex debate on Chinese Weibo. Since various actors published many scattered Omicron-related weibos and highly diverse topics are not conducive to science communication analysis, we selected three related hot themes based on previous research (Tsao et al., 2021; Wang et al., 2020) and platform observation: Vaccines (prevention before infection), Symptoms (of Omicron), and Medicines (treatment after infection). According to these three themes, weibos, which initially spanned a vast period and had mixed contents, were divided into three relatively straightforward parts.

A weibo generally includes the text, the comment text, and the number of reposts. The text contains invisible information such as issues, topics, frames, interactions, and positions. We use content analysis to code and classify the text to examine the production and dissemination of scientific content by different actors. We also use social network analysis to evaluate whether the text is quoted, paraphrased, questioned, or communicated to characterize the interaction between the actors. The number of reposts is an important index to measure the degree of information diffusion: More reposts means greater communication power on Weibo (Lu et al., 2021). The number of reposts is a specific value and can be analyzed by simple statistics. Comments are direct feedback to the text, and more positive comments mean higher approval of the weibo (Hou et al., 2021). Since the number of comments is enormous compared to weibos, we use automated tools to analyze them.

4.2. Sampling

4.2.1. Classification of Actors

Actors in science communication can be divided into groups, including scientists, organizations, media, and the public (Masduki, 2021). However, due to their profession, status, and background, science communication actors on Weibo are more diverse and need to be further categorized. Based on previous literature and Weibo observation, scientists were further categorized into public health experts with positions in national health authorities and general doctors without official backgrounds (Nisbet, 2009). According to the scope of their functions, organizations are divided into health organizations and government organizations (Jin et al., 2022; Nisbet, 2009). Media are divided into central and local media according to the scope and level of the audience (Nip & Fu, 2016). The public, more active in science communication, is divided into journalists, who have experience in news production and information dissemination, and general individuals, who have little influence (Zeng & Li, 2020).

4.2.2. Selected Actors' Accounts

Based on their authentication information, Weibo officially classifies accounts into different industries, such as government, media, health, economy, sports, and personal. Moreover, it rated the top 100 most influential industrial Weibo accounts monthly according to four dimensions: dissemination intensity, service quality, interaction intensity, and identification degree (People's Daily Online & Sina Weibo, 2020). Based on the development of Omicron, we set the time range from November 9, 2021, to June 30, 2022. Using the keyword "Omicron," we checked the weibos of each account on the list and found that 40 had published weibos about Omicron (see Table A in the Supplementary File). These 40 accounts are "analyzable" and "representative" science communication actors, as they are among the most influential in their industry and have published weibos related to Omicron.

4.2.3. Sample Collection and Cleaning

We used a self-written Python program to download all weibos containing the keyword "Omicron" from the 40 Weibo accounts (Guo et al., 2021). Then, the collected weibos were manually checked individually, deleting repeated, vaguely expressed, and meaningless posts, leaving 752 valid sample weibos. We also collected comments under these weibos, yielding 3,247,136 valid comments once meaningless content, such as ads and those purely made of symbols or numbers, had been removed. Finally, according to the three themes classified by the method (Section 4.1), 752 valid samples (and their comments) were divided into three parts (see Table 1) and analyzed separately.

4.3. Content Analysis

4.3.1. Coding Rules

We analyzed the content and communication strategy of weibos from four aspects: issue, topic, frame, and position (see Table 2):

- Issue: According to the communication contents, the weibos are divided into progress, politics, science, international situation, and risk (Hu et al., 2021).
- Topic: Under the three themes of Vaccines, Symptoms, and Medicines, the core topics of communication contents are extracted respectively, and specific topics are obtained through classification (Hu et al., 2021; Khoury et al., 2021).
- Frame: Four science communication frames are used to describe the writing logic of Weibo text, namely the contextual frame, contrasting frame, emphatic frame, and declarative frame (Gao et al., 2021; Khoury et al., 2021).
- Position: Focusing on the inspirational words in weibos, the sample positions are classified into three categories—positive, neutral, and negative—based on grammar and sentence meaning (Gao et al., 2021; Xu et al., 2021).

Distilling issues enable us to find the domain to which weibos belong quickly. Then we identify the specific events and objects discussed in weibos by coding topics (Hu et al., 2021). The frame is widely used to describe communication strategies, which can reflect the intentions of science communicators (Zou et al., 2021). Clarifying the position also helps us better understand the scientists' communication intentions and strategies (Haythornthwaite, 1996).

4.3.2. Coding and Reliability

Two researchers screened and categorized samples according to the coding table. Two coders were trained before jointly coding the first 20% of the samples. Intercoder reliability scores were calculated using Scott's pi coefficient (π; Krippendorff, 2018). The scores all exceed 75%, indicating high coding reliability. When different opinions appeared, the coders chose a suitable one after discussion.

4.4. Social Network Analysis

Social network analysis can describe and measure the relationships between actors and analyze the information and resources behind the relationships (Wasserman & Faust, 1994). We used social network analysis to verify and describe the interaction behaviors (including reposting, quoting, exchange, question, @) between different actors. The number and direction of interactions between actors are counted and made into a 40 × 40 matrix. Moreover, the matrix plots into a directed interaction network diagram using the social network analysis software Gephi. The interaction network diagram consists of three components: actors (network nodes), connections (network links), and boundaries (Oliveira & Gama, 2012). The degree of centrality determines the size of the network nodes. The larger a node is (the more extensive the degree of centrality), the more it interacts with other nodes. The network link indicates the interaction between two nodes, and the color of the link corresponds to the information source node (e.g., if A quotes/forwards the content of B, the color of the link corresponds to the color of B node), and the more interactions are, the thicker the link is.

Table 1. Number of sample weibos.

	Scientists		Organizations		Media		The public		
Themes	Public health experts	Doctors	Health organizations	Government organizations	Central-level media	Local media	Journalists	Individuals	Total (%)
Vaccines	4	92	31	39	30	27	57	15	295
Symptoms	5	89	27	29	52	37	72	21	332
Medicines	2	48	8	7	10	19	22	9	125
Total	11	229	66	75	92	83	151	45	752

Table 2. The dimension and indicators of coding.

Dimension	Themes	Indicators	Description
Issue	Vaccines, Symptoms, and Medicines	Progress	Emphasizing the efforts made by human beings to cope with Omicron and its progress
		Politics	Describing the Omicron response policies introduced by the state, government, officials, and other authorities
		Science	Demonstrating scientific knowledge related to Omicron and the interpretation of scientific knowledge
		International situation	Evaluating international cooperation to respond to Omicron or compare medical conditions between countries.
		Risk	Emphasizing the adverse health effects of Omicron infection and the crisis that Omicron has brought to society and the economy
Topic	Vaccines	Prevention effects	Comparing the efficacy of various vaccines against Omicron
		Research development	Displaying progress in vaccine development, marketing, and use
		Side effects	Emphasizing side effects or risks of vaccination
		Usage suggestions	Suggesting vaccination tips and recommendations for different populations
		Vaccination work	Describing vaccination rates and doses
	Symptoms	Characteristics	Comparing and contrasting the similarities and differences between Omicron and other Covid-19 strains, such as gene sequence, variation, appearance, infectivity, etc.
		Infection symptoms	Demonstrating the health effects of Omicron infection, such as symptoms, rates of serious illness, mortality, hospitalization rates, etc.
		Social influence	Emphasizing the adverse social effects of Omicron, such as the functioning of the medical system, the functioning of the social system, social fear, etc.
		Preventative measures	Suggesting measures to prevent Omicron infection, such as wearing masks, disinfection, vaccination, hand washing, etc.
		Disease treatments	Describing the treatment modalities after Omicron infection, such as nucleic acid testing, medications, hospitalization, infusion, injection, etc.
	Medicines	Drug effects	Comparing the effect of different drugs in the treatment of Omicron
		Research development	Showing progress in medicine development, marketing, and use
		Side effects	Emphasizing side effects or risks of medicines
		Usage suggestions	Suggesting tips and recommendations for the use of different medicines
		Application situation	Describing the sales and use of medicines
Frame	Vaccines, Symptoms, Medicines	Contextual frame	Pointing out the context in which scientific knowledge is generated and the prior social experience or research process that enhances the credibility of scientific knowledge.
		Contrasting frame	Carrying out different viruses, vaccines, or medicines to highlight the main features of a particular vaccine or medicine
		Emphatic frame	Emphasizing the seriousness of virus infections, the importance of vaccines or medicines, and the presence of a specific tone of exclamation, command, or appeal
		Declarative frame	No excessive expression techniques are used, and the content is published straightforwardly

Table 2. (Cont.) The dimension and indicators of coding.

Dimension	Themes	Indicators	Description
Position	Vaccines, Symptoms, Medicines	Positive	Without fear of Omicron, support or praise vaccines and medicines
		Neutral	No apparent position
		Negative	Fear of Omicron, opposition or criticism of vaccines and medicines

4.5. Sentiment Analysis

For comment sentiment recognition, we used SnowNLP, a dictionary-based Python database for Chinese sentiment analysis (Chen et al., 2018). Sentiment analysis with big data usually includes sentiment dictionaries and machine learning. A sentiment dictionary is suitable for low-granularity texts (with shorter lengths), with the advantage of speedy procedures and high accuracy (Chen et al., 2018). We employed the Snow NLP (sample words shown in Table 3) for sentiment analysis because the sample comments were mostly short sentences or texts (Lan, 2013). In practice, we first split the 3,247,136 sample comments into words. By comparing the words in the text of the comments with the words in SnowNLP, we calculated the sentiment of the comments. The output range is [0, 1]: When the sentiment value is [0, 0.33], it indicates the comment is negative (e.g., you are hurting people); [0.33, 0.66) is neutral (e.g., 2022 is half over); [0.66, 1] is positive (e.g., the popular science articles are good).

5. Findings

5.1. Actors and Contents

5.1.1. Vaccines

Among the 295 sample weibos, scientists (*n* = 96) had the largest number of weibos, followed by the public (*n* = 72) and organizations (*n* = 70). The number of science issues (*n* = 169) was the highest, focusing on the preventive effects of different vaccines (such as BNT162b2 and mRNA-1273) or vaccination conditions (such as one to three shots and single or mixed vaccines). Public health experts, doctors, and health organizations are the more active actors discussing scientific issues. They have medical backgrounds and are good at presenting vaccine-related medical knowledge to the public. The number of progress issues (*n* = 63) was moderate. The content was mainly about the progress of vaccine development, which did not generate a lively discussion among different actors, only being published as news.

Vaccine efficacy was a concerning topic for most actors (*n* = 110), emphasizing that existing vaccines, although ineffective in preventing infection, provided some protection against severe illness, hospitalization, or death. Doctors are most concerned about vaccine efficacy and like to emphasize the efficacy of vaccines—for example, "vaccination will not save you from infection, but it will save your life after you get it." Weibos of usage suggestions (*n* = 85) and vaccination work (*n* = 36) were intrinsically linked to persuading the public to get the whole new vaccine from the perspective of doctors and the government, respectively. Most actors describe the efficacy and safety of the vaccine with solid trust.

The declarative frame (*n* = 128) was employed the most, consistent with the characteristics of Weibo as a short text. Except for public health experts, other actors are fond of using the declarative frame to post weibos, which may even have a specific "command" tone, such as "the safety of domestic vaccines is still good, so if you have elderly people at home who have not yet been vaccinated, do it quickly!" The contextual frame (*n* = 70) and contrasting frame (*n* = 69) were often used. The contextual frame was preferred by journalists, who tended to publish longer weibos with adequate background information about vaccines. Most journalists seem to voluntarily join in the mobilization for vaccination, actively presenting the beneficial nature of vaccines and inspiring users' trust in vaccines by citing social cases. Doctors prefer to use the contrasting frame to compare different vaccines with data.

Most samples (*n* = 233) held a positive attitude toward vaccines, and 56 were classified as neutral. Only six samples were negative toward specific vaccines instead of being anti-vaccination in general. Most doctors actively promote vaccines, trying to stimulate public willingness to vaccinate by demonstrating their efficacy and safety. Only a few doctors cite medical studies on vaccine side effects. The full coding results of vaccines are provided in Tale B of the Supplementary File.

Table 3. The example of emotion words with sentiments.

Sentiment dictionary	Sentiment	Sample words
SnowNLP	Positive	Happy, trust, safe, peace, clear, smooth, believable, reliable
	Neutral	Think, shyness, imagine, stop, wait, longing, precision, then
	Negative	Lying, cheating, stupid, fear, rumor, mess, scary, crazy

5.1.2. Symptoms

Among the 332 sample weibos, scientists (*n* = 94) posted the most, followed by the public (*n* = 93) and media (*n* = 89). More than half were science issues (*n* = 184), which dealt mainly with the mutation characteristics of Omicron. Doctors often discuss science issues, preferring to present and paraphrase medical papers related to Omicron and to comment on the results of the papers. When Omicron first appeared, doctors held widely diverse opinions. However, as the epidemic progressed, most doctors agreed that "Omicron is extremely contagious, but the lethality rate is low, and we still need to be cautious about it." Journalists often discussed risk and international situations to highlight the threat of Omicron, explaining that Omicron is causing much trouble abroad to convince the domestic public to be cautious.

Infection symptoms (*n* = 123), social influence (*n* = 105), and characteristics (*n* = 78) were the topics of most actors' weibos, describing Omicron's symptoms and highlighting its potential adverse social effects. There is an inherent consistency in topics between different actors. They were all very active in presenting the threat of Omicron, constantly informing the public about its symptoms, sequelae, and social threats. In the early transmission stages, all actors portrayed Omicron as the "most infectious Covid-19 variant." Although in the late stages of transmission, many studies have shown that Omicron has low rates of severe illness and mortality, all actors continued to emphasize that "Omicron should not be taken lightly."

Concerning expression, 105 sample weibos used a declarative frame. The weibos were similar to short news messages, mainly sharing the latest findings on Omicron's infectious features and genetic characteristics. Of the sample weibos, 98 used contextual frames. The context was mainly from medical research papers, which promoted public understanding of Omicron by reporting scientists' findings. Ninety-four samples used contrasting frames, most of which compared Omicron with Alpha and Delta. All these variants of Covid-19 were slightly different in infectivity, rates of severe illness, hospitalization, and lethality. These weibos comparing these mutant strains were often used to raise public awareness of the crisis by highlighting the infectious power of Omicron.

Most actors' weibos were neutral (*n* = 183), emphasizing the strong infectiousness of Omicron while also describing the low rate of severe illness and lethality. Doctors, in particular, were more objective and detailed in their presentation of Omicron, often citing research-validated ideas and hypotheses to convey relatively complex scientific information to the public. There were also weibos with negative positions (*n* = 56) bent on emphasizing the threat of Omicron, which may arouse public concern and cause unnecessary panic. The full coding results of Symptoms are provided in Table C of the Supplementary File.

5.1.3. Medicines

Among the 125 sample weibos, scientists (*n* = 50) posted the most, followed by the public (*n* = 31) and media (*n* = 29). The progress issues (*n* = 57) were the most, followed by the science issues (*n* = 33). Since there was no effective medicine for Omicron, mainly treated with antiviral medicines and antibiotics, the research and development of medicines, drug effects, and side effects were all actors' concerns. Scientists, organizations, and media were actively involved in presenting and discussing some medicines and related new development.

The most popular topic was research development (*n* = 48), covering medicine development, clinical trials, and marketing approvals. Doctors and media focused more on this topic. Doctors mainly relayed the clinical trial results of some Covid-19 medicines, such as Paxlovid by Pfizer and Molnupiravir by Mercer. Drug effects (*n* = 31) focused on the effects of medicines on hospitalization, severe illness, and mortality, which raised the concern of many individuals. For the average individual, the efficacy and safety of the medicine are of primary concern.

The contextual frame (*n* = 44) was the most frequent expression to promote public understanding of various medicines by providing background. Most people do not understand the process of Covid-19 medicine development and how it works, only having a vague impression that "effective medicines for viruses are hard to develop." The main actors of medicine science communication using context were not individuals but doctors with professional backgrounds and some journalists who focus on related topics. A contrasting frame (*n* = 35) was used to compare the research and development progress, curative effects, and prices of different medicines.

Positive (*n* = 55) and negative positions (*n* = 58) were very close, and the neutral position (*n* = 12) was limited. Because some medicines were still immature, actors' attitudes were greatly divided. Actors with a negative stance believed that "it is impossible to develop an effective medicine for Omicron in a short period" or "there is no need to develop an effective medicine for Omicron." Positive actors believed that "existing medicines have achieved some results in treating severe illnesses, and we should support them." The full coding results of medicines are provided in Table D of the Supplementary File.

5.2. Interactions

5.2.1. Vaccines

Figure 1 shows the network diagram of the interactions of different actors under the Vaccine theme. Most of the connected lines are gray, which means doctors are the most dominant information source, and the vaccine science weibos posted by doctors triggered massive

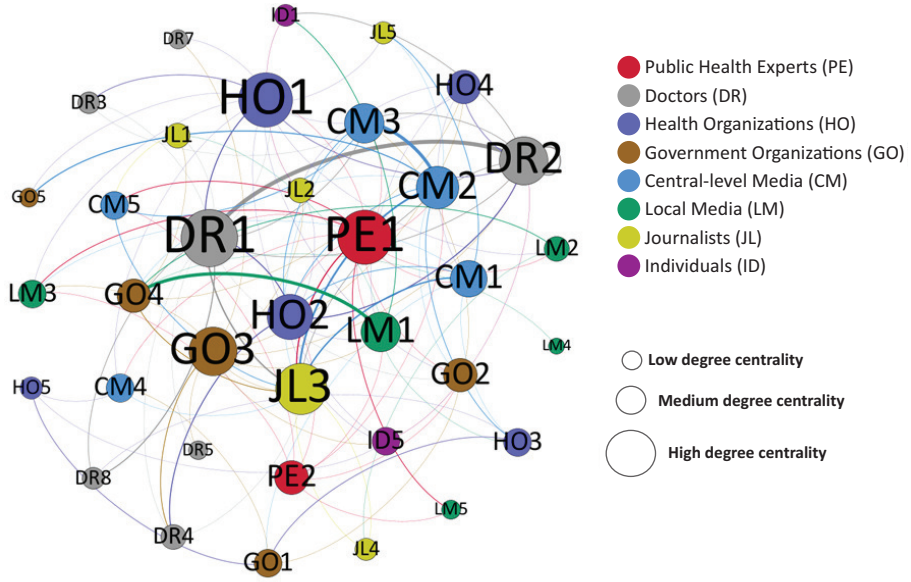

Figure 1. Interaction of the actors (Vaccines).

citations and discussion. In particular, DR1 and DR2 have a high degree of centrality and frequently interact with each other. Public health experts have a prominent degree of centrality, and their published weibos are more widely cited, but they are less likely to cite content published by others. Health organizations and central-level media produced content that generated more positive interactions, had some official stances and provided some original vaccine news. In addition, government organizations and journalists with large nodes (e.g., GO3, GO4, JL3, etc.) interact with other actors by quoting and asking questions. In terms of vaccine information distribution, they are more like intermediaries, paraphrasing original content published by other actors.

5.2.2. Symptoms

Figure 2 shows a network diagram of the interactions of the different actors under the Symptoms theme. Weibos posted by public health experts were likely to be processed and cited by central-level media. Government organizations and health organizations often reposted weibos published by central-level media. To some extent, the central-level media acted as a communication intermediary between public health experts and organizations (e.g., PE1–CM2–HO4, PE1–CM4–CM1–HO2, etc.). The content published by doctors often triggered extensive and direct interactions; for example, DR1, DR2, and DR5 were more centralized, and there were

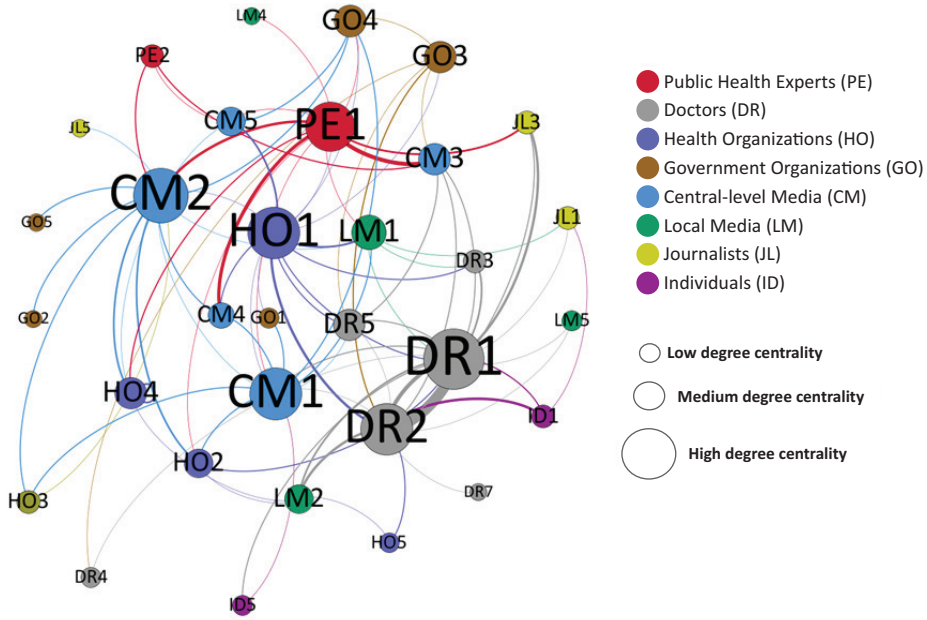

Figure 2. Interaction of the actors (Symptoms).

frequent interactions not only among them but also with other actors.

5.2.3. Medicines

Figure 3 shows the network diagram of the interactions of different actors under the Medicines theme. Weibos posted by central-level media generated the most interaction, followed by health organizations, public health experts, and government organizations. The scientific knowledge about medicines was more specialized than vaccines and diseases. These actors, with official backgrounds, were responsible for the science communication of medicines, and the content they delivered was more accessible so that they could generate a broader range of interactions. Weibos published by nodes such as DR1 and DR2 contained too much medical knowledge and academic research. Although they had a significant centrality, the interactions were limited to doctors.

5.3. Impacts

5.3.1. Vaccines

An average number of reposts refers to the ratio between the number of forwarded weibos and the total number of weibos. The attitude proportion of comments refers to the ratio of positive, neutral, and negative comments to total comments. Figure 4 shows that public health experts had the best science communication, with an average of 35,479 reposts per weibo, and the positive comments were 47.81%, while the negative comments were 14.57%. Weibo posts by central-level and local media were more recognized by the audience, with more than half of their comments being positive. Central-level media and doctors were also influential, with an average of over 200 reposts. Vaccine science communication has a practical impact on public sentiment, which received many positive comments and feedback.

5.3.2. Symptoms

As shown in the right of Figure 5, Symptoms' science communication moderately impacted public sentiment, with many reposts and more positive comments than negative ones. Public health experts had the most potent communication power. Their weibos had a relatively high percentage of positive comments (47.81%), and the average number of reposts exceeded the sum of the other seven actors. Central-level media and doctors' communication power were the second and the third. Local media was ineffective, with fewer reposts and more neutral comments than positive ones.

5.3.3. Medicines

As shown in Figure 6, Medicines' science communication had a moderate impact on public sentiment, with many reposts, but the attitude of the comments was polarized. The average number of public health experts and central-level media reposts exceeded 4,000. Public health experts, doctors, health organizations, local media, journalists, and individuals had more negative comments than positive ones. Government organizations and central-level media had more positive comments than negative ones. Government organizations and central-level media published mainly authorized medicines already approved for marketing. Doctors were

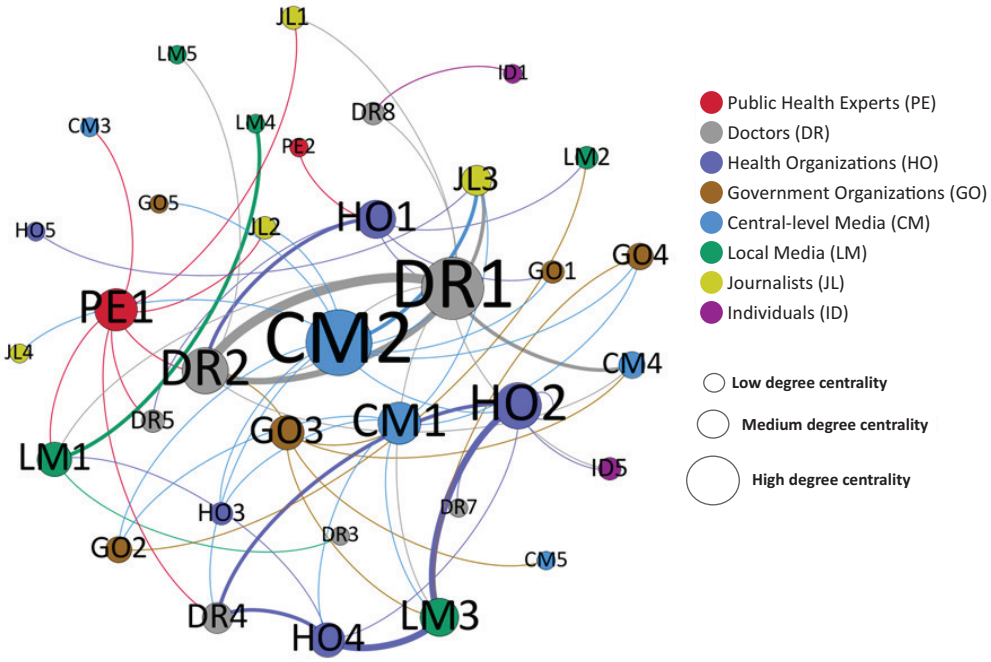

Figure 3. Interaction of the actors (Medicines).

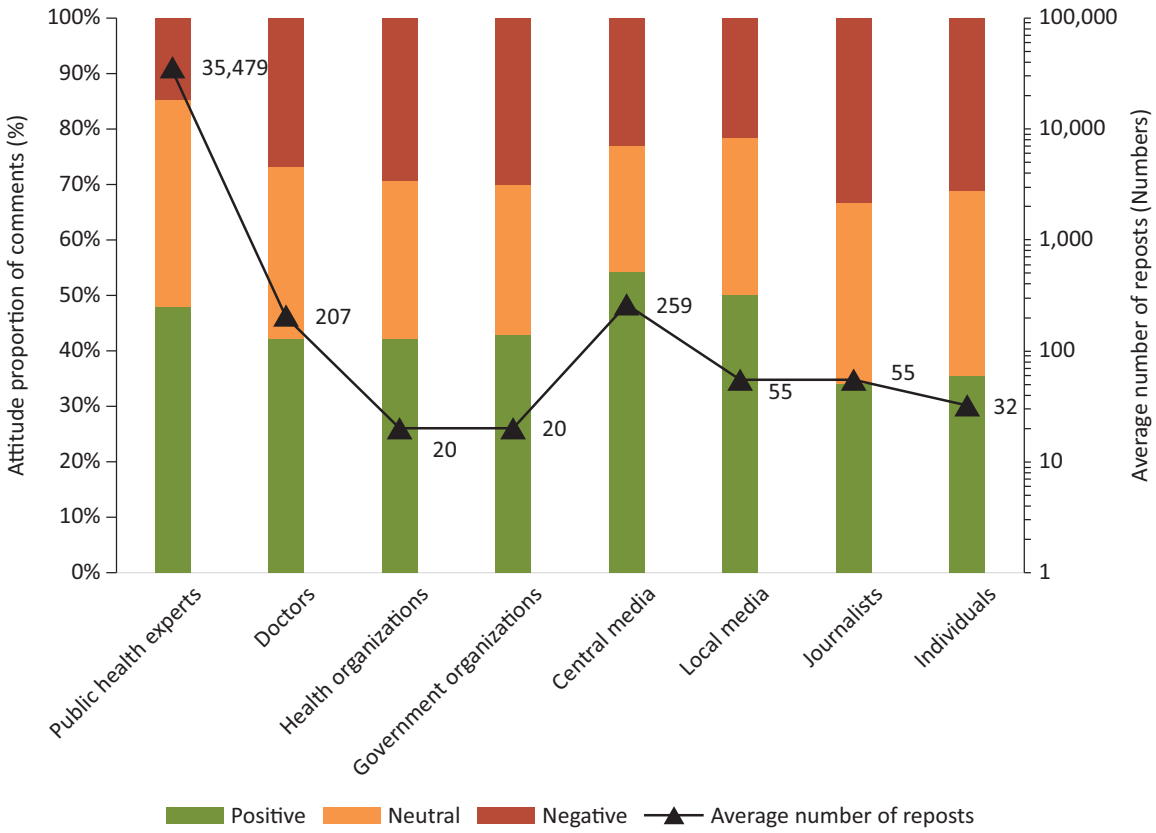

Figure 4. Impact of weibos on public sentiment (Vaccines).

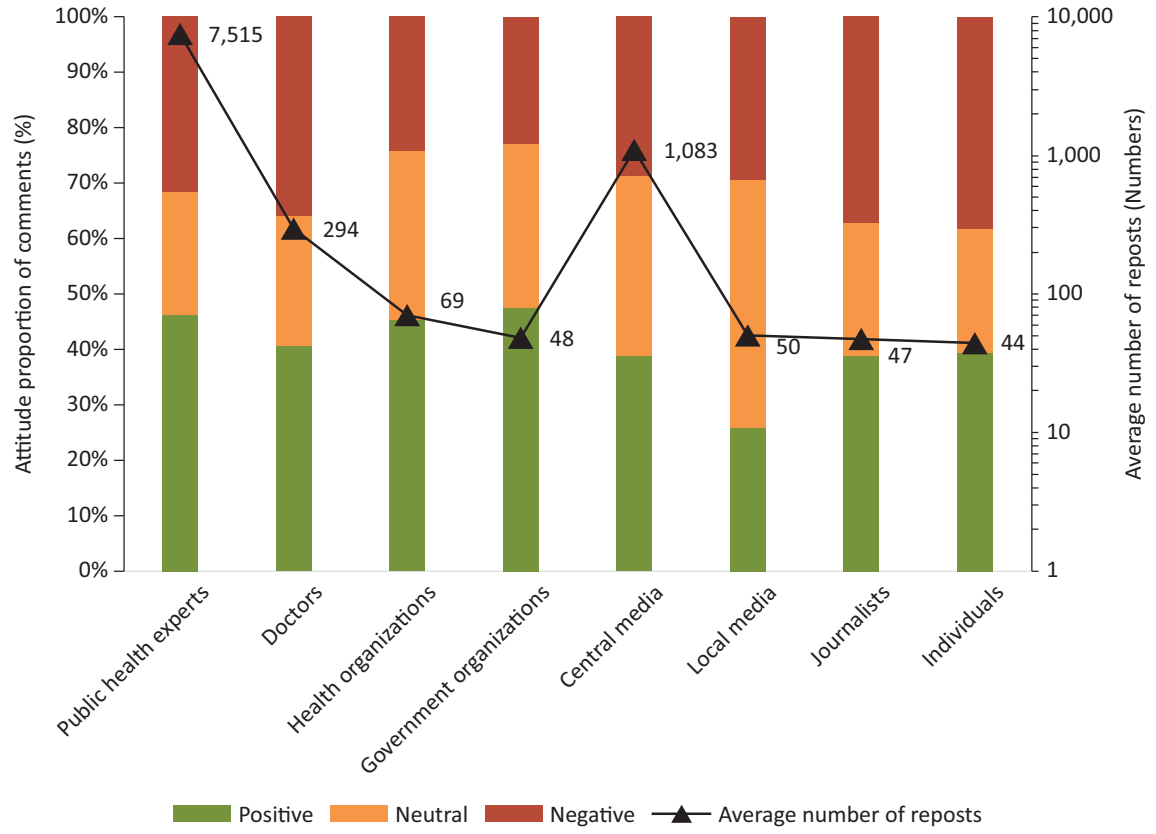

Figure 5. Impact of weibos on public sentiment (Symptoms).

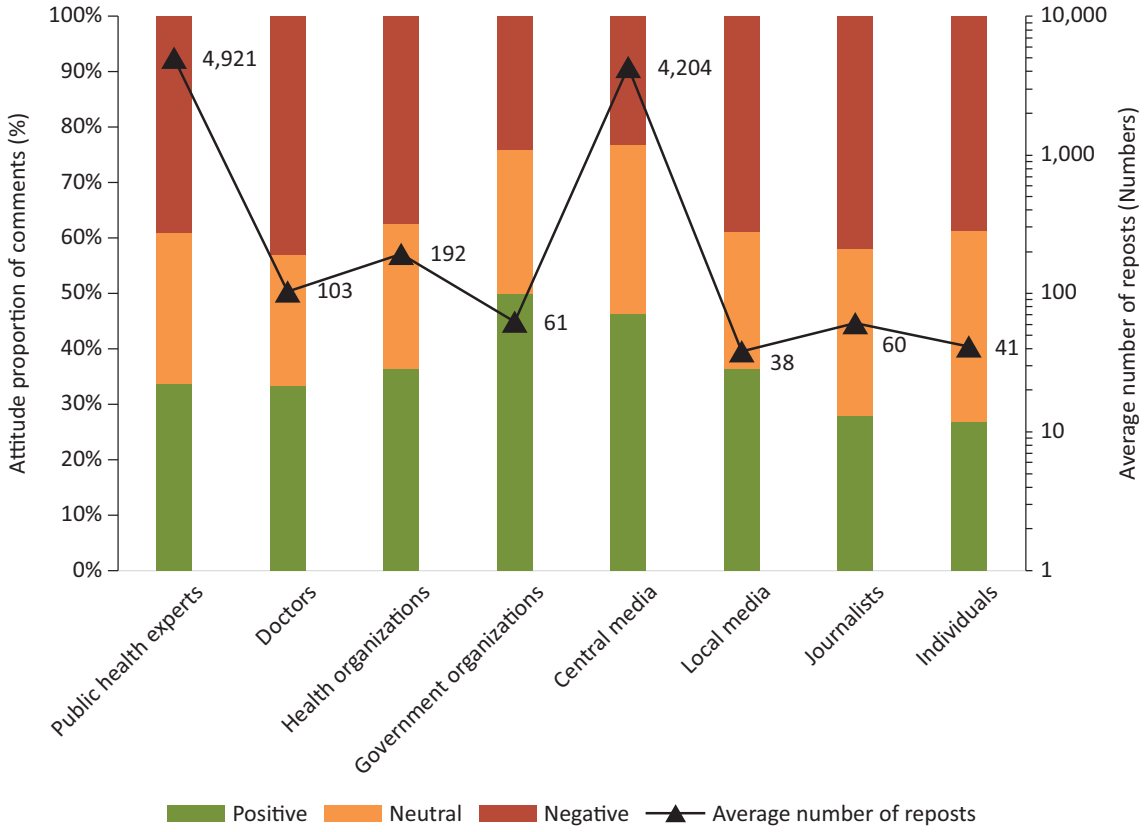

Figure 6. Impact of weibos on public sentiment (Medicines).

concerned about a much more comprehensive range of medicines, many of which were clinical trials of drugs. The academic content also limited the efficacy of doctors' communication.

6. Discussion and Conclusion

We selected 40 representative actors and 752 valid sample weibos to explore the scientific communication of Omicron on Weibo. Based on previous studies and sample characteristics, we divided the actors into eight categories. Under the themes of Vaccines, Symptoms, and Medicines, we examined the content of the actors' communication with content analysis, presented the interactions of different actors using social network analysis, and assessed the impact of weibos on public sentiment using SnowNLP and descriptive statistics.

Research has shown that scientists are the primary science communication actors within traditional media (Burns et al., 2003). Our research confirmed that scientists (public health experts and doctors) remain the most critical actors on Weibo, generating and disseminating a more objective and comprehensive knowledge of Omicron and bringing the public closer to science. Although these scientists also faced official guidance and scrutiny, they presented scientific knowledge about Omicron to the public by paraphrasing research papers. Doctors were among the actors with the highest number of weibos under all three themes, actively participating in the production and transmission of Omicron knowledge. Public health experts focused on science issues and surpassed at using contrasting and contextual frames to paraphrase esoteric medical research results related to Omicron into a form that ordinary people may easily understand and inspire public thinking.

The public's understanding of scientific information depends on how actors introduce, interpret, and evaluate scientific facts (Decieux, 2016). In this study, the specific topics focused on by actors with different identities, backgrounds, and jobs differed. However, the content posted by different actors was internally consistent. This suggests that scientific communication between different actors on Weibo is not entirely free and unregulated. Weibo is a "relatively" free space, and communication activities are still subject to national policies and related regulations. Certain information that is officially emphasized and promoted often generates more discussion, and official assertions about Omicron influence the perceptions of other actors. First, under the Vaccines theme, most actors strongly emphasized the safety and efficacy of the Covid-19 vaccine. There was almost no anti-vaccine rhetoric, consistent with the Chinese government's strategy to promote universal vaccination against Covid-19 (Xu et al., 2021). Second, under the Symptoms theme, there was unanimous consensus among all actors on the perception of Omicron as a "highly infectious, mildly symptomatic, but still noteworthy variant of Covid-19." Since the outbreak of

Covid-19, China has maintained a "zero-Covid" disposal policy, isolating and treating infected cases at the earliest opportunity. The actors' statements followed the national policy that Omicron still requires the continued use of the "zero-Covid'' disposal method. Third, under the Medicines theme, although different actors had different perceptions of the various Covid-19 medicines, they essentially held a positive position on domestic medicines.

Brossard and Nisbet (2007) stated that in science communication, the scientific information presented by news media plays a vital role in general cognition and emotion. From interactions between different actors, we found that central-level media was a crucial intermediary for communication or interaction between different actors. Many actors reproduced the information published by central-level media, acting as disseminators rather than producers. With regards to the themes of Vaccines, Symptoms, and Medicines, weibos published by public health experts, played the role of policy guidance, and those published by doctors had more widespread scientific knowledge. Central-level media interpreted public health policies and Omicron knowledge published by scientists, behaving as a channel for relaying and diffusing science. It serves as a link between the public and scientists, promoting public understanding of medical knowledge (Wintterlin et al., 2022).

Science communication on Weibo influenced public sentiment to a certain degree. Overall, the sum of positive and neutral comments was much higher than negative comments under the three themes, suggesting that the public tended to have a positive attitude toward weibos' content. The number of reposts also showed that Weibo is gaining public acceptance. Specifically, scientists usually generate mass reposts and have more positive comments than other actors. In the age of social media, scientists still strongly influence the transmission of scientific communication about Omicron. Central-level media had many followers, and their weibos triggered many reposts and received sound diffusion effects. It also inspires us to take advantage of media and organizations with a solid fan base when disseminating scientific information on social media platforms (Liao et al., 2020).

The findings and conclusions of this article can bring at least two contributions. At the theoretical level, the study confirms the ability and status of scientists and central-level media in science communication on Weibo, contributing to actor innovation in science communication theory in the age of social media. At the methodological level, this article uses a mixed research approach that helps to inspire the integration and innovation of content analysis, social network analysis, sentiment analysis, statistical analysis, and other methods in science communication.

This article also has some shortcomings. We selected 40 of the most influential Weibo accounts as the sample, inevitably ignoring some less influential accounts. Such a sampling method will make the results biased regarding the number of weibos and reposts. We divided the actors of science communication into eight types according to previous research and sample characteristics, which can cover the samples and apply them to health issues. Nevertheless, there is still room for further expansion and refinement of the classification. We examined the number of weibo reposts and commented sentiments to evaluate the impact on public sentiment. However, other indicators, such as the number of likes, were not included.

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Conflict of Interests

The authors declare no conflict of interests.

Supplementary Material

Supplementary material for this article is available online in the format provided by the author (unedited).

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