Postprint: A Study on the Subjects of Online Rumor-Refuting Information in Public Health Emergencies on Social Media

Authors: Ruonan Jia, Wang Xiwei, Sun Yujiao

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Abstract

[Purpose/Significance] Analyzing the types, interrelationships, community structures, and dissemination effects of online rumor-refutation information subjects from multiple perspectives facilitates the identification of key rumor-refutation information subjects and effective diffusion patterns of online rumor-refutation information, which is of significant importance for strengthening public opinion guidance and maintaining social stability during public health emergencies. [Method/Process] This study selects the "Shuanghuanglian" rumor-refutation incident during the COVID-19 pandemic, constructs a rumor-refutation subject relationship network using Neo4j, and employs the Louvain community detection algorithm to partition network communities. Through content analysis and regression analysis, it compares and analyzes the content characteristics and refutation strategies of online rumor-refutation information subjects, and constructs a "subject-content" bipartite network to examine how different information subjects and network communities promote the dissemination of rumor-refutation information in social media and to identify effective refutation methods and strategies. [Result/Conclusion] The research findings reveal that government and mass media are the primary actors in online rumor refutation. The government most commonly utilizes strategies of direct rumor refutation, whereas mass media adopt the opposite approach. Content characteristics exert differential influences on the dissemination effectiveness of rumor-refutation information.

Full Text

Research on Subjects of Online Rumor-Refuting Information for Public Health Emergencies in Social Media

Jia Ruonan[1], Wang Xiwei[1],[2],[3], Sun Yujiao[1]

[1]School of Management, Jilin University, Changchun 130022
[2]Research Center for Big Data Management, Jilin University, Changchun 130022
[3]Cybersecurity Governance Research Center, National Academy of Development and Security, Jilin University, Changchun 130022

Abstract:
[**Purpose/Significance**] Analyzing the types, interrelationships, community structures, and dissemination effects of online rumor-refuting information subjects from multiple perspectives helps identify key refuting subjects and effective diffusion patterns. This plays a crucial role in strengthening public opinion guidance and maintaining social stability during public health emergencies. [**Method/Process**] This study selected the "Shuanghuanglian" rumor-refuting case during the COVID-19 pandemic, constructed a refuting subject relationship network through Neo4j, and used the Louvain community detection algorithm to identify network communities. Through content analysis and regression analysis, we compared and analyzed the content characteristics and refuting strategies of different subjects, and constructed a "subject-content" two-mode network to examine how different information subjects and network communities promote rumor-refuting information dissemination in social media, as well as effective refutation methods and strategies. [**Result/Conclusion**] The findings reveal that government and mass media are the primary actors in online rumor refutation. The government most commonly uses the strategy of countering rumors with evidence, while mass media tend to do the opposite. Content characteristics have varying effects on the dissemination effectiveness of rumor-refuting information.

Keywords: social media; public health emergency; online rumor refutation; information subject
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Public health emergencies are typically characterized by suddenness, uncertainty, and high risk. With the rapid popularization of social networks, social media has become an important channel for emergency response during public health crises. However, alongside the dissemination of authentic information, social media also serves as a channel for spreading misinformation and online rumors. The *2019 Online Rumor Governance Report* released by Sun Yat-sen University and Tencent, under the guidance of the Cyberspace Administration of China and the Center for Reporting Illegal and Harmful Information, indicates that high-profile online rumors exhibit visualized dissemination forms and globalized reach. In the current technological context, online rumors spread faster, through more channels, with broader influence and more diverse content formats, sometimes affecting public scientific cognition, disrupting normal public opinion order, and threatening the construction of a safe, healthy, clear, and orderly online environment [1-2]. Faced with the challenge that "rumors spread easily while refutations struggle" during public health emergencies, seek-

ing reasonable and effective refutation measures, jointly purifying cyberspace, and creating a favorable information dissemination environment have become shared concerns for both government and academia following the COVID-19 outbreak.

2 Literature Review

2.1 Online Rumors about Public Health Events in Social Media

Online rumors refer to uncertain information circulating on the internet [6]. While numerous studies have demonstrated that social media serves as an active and effective communication tool for crisis communication and emergency response across various incidents, scholars have also paid considerable attention to its potential for misuse. Issues such as information overload in open-access social media and the inability to accurately identify data exacerbate the likelihood of rumor propagation [7]. Inaccurate data, unverified rumors, and even malicious false information disseminated on social media [8] can sometimes influence public perception of factual situations. Social media has both positive and negative impacts on public health event prevention and understanding [9]. Research shows that during public health emergencies, the spread of online rumors on social media poses a threat to global health and has become a major challenge in the public health domain [10]. If not promptly clarified and controlled, online rumors can easily trigger public opinion crises. Therefore, timely and effective rumor control is crucial, and research on online rumor governance and refutation in social media during public health emergencies is gaining academic attention.

2.2 Online Rumor Refutation in Social Media

Online rumor refutation refers to information clarification, rebuttal, and correction targeting rumors to explain the truth and reduce the negative impact of false rumors—currently a common method for controlling and governing various types of online rumors [4]. International research on online rumor refutation has focused on refuting subjects, effectiveness, and impact on rumor spread. Based on situational crisis communication theory, scholars have proposed three refutation strategies—countering, denying, and criticizing—and examined their dissemination effects and public willingness to accept and spread refuting information [11]. Social network analysis and content analysis of rumor data have confirmed that interventions can effectively reduce adverse effects [12]. Machine learning techniques can identify refuting subjects [13] and explore the roles of government and media as refuting entities [3]. Domestic scholars have primarily investigated cooperative behavior patterns, dissemination mechanisms, and influencing factors of online rumor refutation in social media, revealing gaps in collaborative refutation mechanisms [2], analyzing temporal dimensions of refutation information diffusion [14], and examining how community structures and

subject characteristics affect collaborative rumor governance [15-16].

2.3 Necessity of Research on Rumor-Refuting Subjects in Public Health Emergencies

Online rumor refutation essentially involves the interaction of different refuting subjects during information dissemination, directly related to their behavioral patterns, action strategies, and information content. Existing research has largely focused on the role and effectiveness of single subjects from limited perspectives. However, given the collaborative nature of rumor refutation and the particularities of public health emergencies, multi-dimensional comprehensive analysis of refuting subjects—including multiple subject types, network communities, content characteristics, and refutation strategies—can help emergency response and crisis management departments understand effective strategies and information dissemination mechanisms. This is crucial for strengthening rumor governance and multi-subject collaborative refutation during public health emergencies.

This study examines a hot rumor-refuting topic during a public health emergency, classifying refuting subject types, constructing relationship networks via knowledge graph tool Neo4j, identifying key communities using the Louvain algorithm, extracting subjects from key communities for content analysis to build a "subject-content" two-mode network, and conducting regression analysis to analyze key subject types, content characteristics, and effective refutation strategies.

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3 Analytical Framework for Rumor-Refuting Subjects in Public Health Emergencies

3.1 Construction of Relationship Network Graph for Rumor-Refuting Subjects

Emergency response networks for public health emergencies typically comprise multiple information subject types. Existing research has categorized social media users discussing incidents into government, media, social organizations, and netizens [17]. Rumor-refuting subjects refer to entities that participate in rumor response through generating, publishing, or disseminating refuting information. Different subject types play distinct roles, and understanding these roles and relationships helps governments and organizations build effective information networks and improve refutation effectiveness. Subject roles manifest not only through creating high-quality refuting content but also by connecting previously disconnected communities. This study classifies refuting subject types and uses Neo4j to construct a visual relationship network graph, where nodes represent subjects and edges represent interactions.

3.2 Community Detection in Rumor-Refuting Networks Using Louvain Algorithm

Community detection divides network communities into sub-communities based on nodes, representing natural community structures [18]. Research shows community detection has practical significance for studying information dissemination hierarchies and public opinion supervision [19]. As social learners, social media users' community structures may significantly impact conveyed information, necessitating better understanding of community structures and content [20]. The Louvain algorithm is a modularity-based community detection algorithm with good performance on large networks, commonly used for social media community discovery [21]. Modularity measures community structure strength, with values of 0.3-0.7 indicating strong community structures [22]. Therefore, this study employs the Louvain algorithm to identify community structures in rumor-refuting subject networks.

3.3 Two-Mode Network Construction and Analysis

During rumor refutation, different subjects can employ multiple strategies or content features simultaneously, while the same strategy or feature can be adopted by multiple subjects. Integrating subject nodes, content nodes, and their relationships forms a "subject-content" two-mode network [23]. Based on content differences, refutation strategies fall into three types: (1) **Countering rumors**—explaining and correcting rumors with factual evidence; (2) **Denying rumors**—simply denying without evidence; (3) **Criticizing rumormongers**—criticizing or threatening punishment. Content features also affect dissemination outcomes: hyperlinks, hashtags, and embedded media (images/videos) can promote interaction by increasing user engagement, though multiple content types may hinder comprehension and increase processing time [24]. This study uses content analysis to identify refutation strategies and content features, constructs a two-mode network to discover subjects' focus and strategies, and employs regression analysis to determine their specific impact on dissemination effectiveness.

3.4 Analysis Framework for Rumor-Refuting Subjects

Figure 1 [Figure 1: see original paper] illustrates the research framework. First, we used LocoySpider V2010SP3 to crawl forwarding, commenting, and liking data from Sina Weibo rumor-refuting topics. Second, based on Weibo's verification rules and actual roles, we classified collected subjects. Third, we used Neo4j to construct subject relationship networks based on forwarding and commenting relationships. Fourth, we applied the Louvain algorithm to identify community structures and key subject types. Fifth, we sampled 400 subjects from key communities for content analysis to identify strategies and features, constructing a "subject-content" two-mode network. Finally, we used regression analysis to examine how strategies and features affect dissemination effectiveness.

4 Empirical Analysis

4.1 Data Sources and Collection

Since the COVID-19 outbreak, numerous online rumors and corresponding refutation topics have emerged, with the "Shuanghuanglian" incident being a typical case [25]. Within a short period, Shuanghuanglian-related topics on Sina Weibo accumulated over 3 billion views and more than 1 million discussions [26]. On January 31, 2020, media reports claiming "Shuanghuanglian oral liquid can inhibit novel coronavirus" caused public misunderstanding, panic buying, and serious adverse consequences for epidemic prevention. Subsequent refutation reports by various media consumed public trust and triggered intense public opinion crises. As one of China's mainstream social media platforms, Sina Weibo had over 200 million daily users tracking the epidemic [27]. Therefore, this study used Sina Weibo as the data source, crawling data under Shuanghuanglian refutation topics including "#Shuanghuanglian oral liquid cannot prevent COVID-19#", "#Please do not rush to purchase and self-administer Shuanghuanglian oral liquid#", "#No strong evidence proves Shuanghuanglian efficacy#", and "#Shuanghuanglian refuted#". The dataset included user nicknames, IDs, likes, forwards, comments, and timestamps, totaling 41,149 entries. After cleaning and preprocessing, 40,383 valid entries remained.

4.2 Data Processing and Results

4.2.1 Subject Types and Relationship Networks Sina Weibo's verification system includes: (1) institutional verification (blue V) for government departments, enterprises, schools, and media; (2) personal verification (red V and yellow V) for influential individual users [28]. Based on collected data, we classified rumor-refuting subjects into four types: government, mass media, science popularization accounts, and ordinary netizens [29]. Using Neo4j and Cypher language to import nodes and edges based on forwarding relationships, we obtained a network with 23,501 nodes and 26,152 edges, including 54 government nodes, 222 mass media nodes, 6 science popularization account nodes, and 23,219 ordinary netizen nodes.

4.2.2 Community Structures and Key Subject Types The Louvain algorithm divided the network into four communities. Table 1 shows community composition and modularity values, while Figure 2 [Figure 2: see original paper] visualizes the community structure. Table 2 presents centrality scores by subject type. The modularity value of 0.65 indicates reasonably strong community structure. The top three communities contained over 90% of nodes, with Community 0 having the most subjects and Community 2 containing the most subject types. Government accounts appeared in different communities from science popularization and mass media accounts, while connections between mass

media and science popularization accounts were relatively weak. Among the top 10 subjects by centrality, 4 were government, 3 were mass media, and 3 were science popularization accounts, primarily from Communities 0 and 2. Results show that government and mass media serve as main connectors within and between communities. In Communities 0 and 1, government connections with science popularization accounts were closer. Community 2 contained the most subject types with denser network structure, facilitating information spread.

4.2.3 Two-Mode Network During rumor refutation, official subjects (government, media, platforms) have always been the backbone, leveraging their authority and organizational power to intervene effectively and influence netizens. Comments, forwards, and likes represent primary netizen engagement. While netizens frequently publish and forward information, their individual influence remains limited compared to government and media, often appearing as information audiences [30]. Effective rumor management depends not only on response strategies but also on public reactions. Therefore, our content analysis focused on posts by government, science popularization, and mass media accounts, treating netizen behaviors as reactions to refuting information.

Based on community detection results, we selected 400 subjects for content analysis to identify refutation strategies and content features, then constructed a "subject-content" two-mode network (Figure 3 [Figure 3: see original paper]). PageRank values, which integrate centrality and network structure to indicate node importance [31], were used to measure strategy and feature prominence. Higher PageRank values indicate broader audience coverage. Table 3 shows that denying rumors was the most adopted strategy, while hashtags were the most common content feature. Figure 4 [Figure 4: see original paper] reveals that government and science popularization accounts prefer countering strategies, while mass media favor denial. Regarding content features, government and mass media frequently use hashtags, whereas science popularization accounts prefer hyperlinks to strengthen evidentiary support.

4.2.4 Rumor-Refuting Information Dissemination Effects To analyze potential relationships between strategies/features and dissemination effectiveness, we employed regression analysis—a predictive modeling technique that uses mathematical models to represent causal or correlational relationships between dependent and independent variables [32]. For the dependent variable, we measured refutation effectiveness using the logarithm of dissemination speed: the logarithm of hourly dissemination volume (total forwards, comments, and likes) during the 24-hour propagation period [33-34]. Independent variables included refutation strategies, content features, and subject follower counts (log-transformed). Content features (hashtags, hyperlinks, embedded media) were coded by usage frequency; strategies were coded as 0=countering, 1=denying, 2=criticizing [24,29].

Linear regression analysis using SPSS 19 yielded results shown in Table 4 . All

variance inflation factor (VIF) values were below 10, indicating no significant multicollinearity. Results show that refutation strategy choice had no significant effect on dissemination effectiveness. Among content features, hashtags had significant negative effects, while hyperlinks had significant positive effects. Embedded media showed no significant impact. Subject follower counts significantly and positively affected dissemination effectiveness.

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5 Discussion

5.1 Subject Types and Community Relationships

Among the four subject types, government and mass media are primary actors in rumor-refuting emergency response, maintaining close connections with other subjects within and across communities—consistent with S. Goel et al.'s findings [35]. Unlike previous research, science popularization accounts emerge as a new subject type playing important roles and maintaining close ties with other subjects. Community division results show closer government connections with the other two subject types, possibly because truth dissemination demonstrates better long-term performance. Science popularization accounts, mostly verified authoritative platforms with rumor-verification functions, have close cooperative relationships with government. In China's political and social environment, mainstream media often serves as a "window" between government and public, forming government-led communication matrices during information dissemination.

During rumor refutation, establishing information exchange mechanisms among government, mass media, and science popularization accounts can accelerate complementary advantages based on their social roles: leveraging government authority to expand dissemination paths, using media professionalism to improve expression and avoid jargon-induced comprehension difficulties, and utilizing science popularization accounts' cognitive advantages to reduce processing time. Additionally, opinion leaders with large follower bases can deliver refuting information faster than other subjects due to strong social ties with followers, enhancing participation. Therefore, targeted training for these opinion leaders can accelerate transformation from passive information recipients to active disseminators, improving rumor-refuting efficiency.

5.2 Information Dissemination Strategies

Empirical results show that refutation strategy selection has no significant impact on dissemination effectiveness. Given different subject natures and social positioning, selecting appropriate strategies based on social roles is more suitable. Among the three strategies, government most frequently uses countering, followed by denying and criticizing. Mass media strategies differ from government—during early public health emergency response, online media prioritize rapid information release [29], making direct denial more immediate.

Media's social nature also requires critical functions [4], making simple, direct denial strategies the fastest response. Science popularization accounts predominantly use countering strategies, aligning with their cognitive positioning.

In public health emergencies, where rumor origins are unclear and false information is difficult to identify, preventing information vacuums that trigger public panic requires government to maximize timely disclosure of accurate information. For government and science popularization accounts, simply denying rumors is relatively ineffective, while criticizing rumor-mongers may affect public trust and cause secondary crises. More effective approaches involve explaining why rumors should not be believed to prevent further spread. The more sufficient the evidence, the higher the credibility and likelihood of quelling rumors while strengthening public trust. Therefore, evidence-based countering is more effective. Conversely, mass media, acting as information "megaphones," emphasize timeliness and require critical functions, making simple denial strategies appropriate for rapid response.

5.3 Content Characteristics of Online Rumor Refutation

Different content characteristics have dualistic effects on dissemination effectiveness. Hashtag quantity shows significant negative impact on dissemination speed, consistent with J. Son et al. [24]. The non-significant effect of embedded media and significant positive effect of hyperlinks differ from previous findings [36], possibly due to varying event types and communication habits affecting information adoption and retransmission willingness. Differences in feature usage preferences across subjects likely stem from varying emphases on timeliness: government and mass media prioritize rapid information delivery, using hashtags to express key themes and help users quickly locate relevant information. Science popularization accounts focus on using authoritative scientific articles and external evidence, often requiring hyperlinks due to Weibo's character limits.

For all refuting subjects, maximizing effective content features for rapid information delivery is key to rumor control and guidance. Cognition of refuting information's context plays an important role in public judgment formation. Subjects can improve information quality and dissemination by appropriately using hashtags and embedded media to enhance content perception. However, excessive hashtags or unrelated tags for exposure cause information overload, ambiguity, and increased processing time, hindering accurate understanding. Weibo's character limit may restrict clarity, weakening public perception and trust. Hyperlinks can supplement external resources and evidence, delivering more concrete, observable information that enhances information value while incentivizing rapid adoption and dissemination.

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6 Conclusions

Theoretical contributions: This study classifies rumor-refuting subjects into government, science popularization accounts, mass media, and ordinary netizens based on Sina Weibo's verification system, constructing a subject relationship network. Through content analysis, we categorize refutation strategies into countering, denying, and criticizing, and build a "subject-content" two-mode network combining content features. This provides a new perspective for research on social media rumor refutation during public health emergencies.

Practical implications: Using the Louvain algorithm, we identified community structures and key subjects in rumor-refuting networks, revealing different subject roles. Regression analysis examined how strategies and content features affect dissemination effectiveness. The findings offer guidance for leveraging different subjects' roles in public health emergencies, helping regulatory agencies better respond to and govern online rumors.

Limitations: (1) The sample selected a single rumor case during a public health emergency within the same cultural and information environment. The applicability of conclusions to other events or contexts requires further verification. Future research should compare multiple event types and regions to enrich findings. (2) This study categorized strategies into three types, but other types may exist, and different subject types may produce varying effects. Future research should explore how different strategy-subject combinations affect outcomes to deepen conclusions.

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Author Contributions

Jia Ruonan: Research concept and framework design, data collection and analysis, paper writing and revision.
Wang Xiwei: Research concept and framework modification, paper revision.
Sun Yujiao: Data collection and preprocessing.

Research on the Subject of Information to Refute Rumors of Public Health Emergencies in Social Media

Jia Ruonan[1], Wang Xiwei[1,2,3], Sun Yujiao[1]

[1]School of Management, Jilin University, Changchun 130022
[2]Research Center for Big Data Management, Jilin University, Changchun 130022
[3]Cybersecurity Governance Research Center, National Academy of Development and Security, Jilin University, Changchun 130022

Abstract: [Purpose/significance] Analyzing the types, mutual relationships, community structure, and dissemination effects of information on the Internet from multiple angles will help to discover the key information subjects and effective diffusion patterns of information on the Internet. It plays an important role in strengthening the guidance of public opinion and maintaining social stability during public health emergencies. [Method/process] The article selected the "Shuanghuanglian" rumor during the new crown pneumonia epidemic, built a network of rumor-defying subjects through Neo4j, and used the Louvain community detection algorithm to divide the network community; through content analysis and regression analysis, the content characteristics and rumor-defying

strategies of the network rumor-defying subjects were compared and analyzed, and a "subject-content" two-mode network was constructed to analyze how different information subjects and network communities promote the dissemination of rumor-defying information in social media and effective rumor-defying methods and strategies. [Result/conclusion] The results of the study found that the government and the mass media are the main actors in the network rumor-defying. The government most commonly uses the strategy of refuting rumors, while the mass media does the opposite. Content characteristics have different effects on the effectiveness of rumor-defying information dissemination.

Keywords: social media; public health emergency; network rumor-defying; information subject

Note: Figure translations are in progress. See original paper for figures.