Research on Factors Influencing the Effectiveness of Online Rumor Debunking in Public Health Emergencies: A Case Study of COVID-19 Pandemic Rumors (Postprint)

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Abstract

[Purpose/Significance] Online rumors during public health emergencies generate severe negative impacts and disrupt social order. By examining the COVID-19 pandemic, this study analyzes the influencing factors of online rumor refutation effectiveness in public health emergencies, aiming to provide decision-making references for enhancing such effectiveness and thereby mitigating social risks associated with online rumors. [Method/Process] Grounded theory is employed to investigate these factors, yielding 22 initial concepts, 12 categories, and 6 main categories. Building upon this foundation, Interpretive Structural Modeling (ISM) and MATLAB matrix analysis are utilized to examine the interrelationships among these influencing factors. [Results/Conclusion] Based on coding results, the influencing factors are integrated into three dimensions—subject, information, and channel—constructing an SIC (Subject-Information-Channel) model analytical framework to analyze the action pathways of each main category on refutation effectiveness. A hierarchical structural model is established, categorizing the influencing factors into foundational, moderating, and acting layers.

Full Text

Preamble

Title and Authorship

A Study on Factors Influencing the Effectiveness of Online Rumor Refutation in Public Health Emergencies: A Case Study of Online Rumors During the COVID-19 Pandemic

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Abstract

[**Purpose/Significance**] During public health emergencies, online rumors generate serious negative impacts and disrupt social order. This paper analyzes the factors influencing online rumor refutation effectiveness during public health emergencies, using the COVID-19 pandemic as a case study, to provide decision-making references for improving refutation effectiveness and effectively avoiding social risks caused by online rumors. [**Method/Process**] Using grounded theory, this study explores the influencing factors of refutation effectiveness in public health emergencies, obtaining 22 initial concepts, 12 categories, and 6 main categories. Based on these findings, the study employs the Interpretive Structural Modeling (ISM) method and MATLAB matrix analysis to examine the relationships among various influencing factors. [**Result/Conclusion**] Based on the coding results, the influencing factors of refutation effectiveness are summarized and integrated into three dimensions: subject, information, and channel. The SIC model analysis framework is constructed to analyze the pathways through which main categories influence refutation effectiveness, and a hierarchical structural model of influencing factors is developed, dividing them into the foundational layer, regulatory layer, and functional layer.

Keywords: public health emergency; online rumor; rumor refutation effectiveness; influencing factors
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The development of the internet and social media has expanded the speed and scope of information dissemination, yet not all widely circulated information is authentic. In recent years, global public health emergencies have increased, such as Ebola, SARS, H1N1 influenza, and COVID-19 [1-2]. During these events, the public's lack of scientific health knowledge creates an internal demand for health information, which stimulates mass media to spread information while also providing opportunities for rumor-mongers to create and disseminate online rumors. Ineffective scientific knowledge and fake news during public health emergencies generate serious negative impacts and disrupt social order. Rumors exist during "information vacuums"—periods when official and expert information is delayed relative to event occurrence [10]. Rumor propagation not only misleads public judgment and affects economic development [12], but can also cause political consequences [14]. Even after rumors subside, risks may not completely dissipate, leaving potential secondary risks [15].

In recent years, research on online rumors and refutation has become a hot topic among scholars worldwide. Foreign scholars P. Meel et al. provide methods for classifying malicious information like rumors at different stages, and discuss popular techniques for addressing these issues from origin, propagation, detection, and containment phases [3]. J. Makhouol et al. reference social science and risk communication theories to discuss how national political, economic, and social contexts affect information processing [4]. Y. Zhang et al. describe the interaction between rumors and refutations based on biomathematical theoretical models [5]. Domestic scholars Ma Ning and Liu Yijun apply principal component analysis to compare the comprehensive influence of "rumor information" and "refutation information" on Weibo, aiming to accurately predict their respective propagation impacts [6]. Li Zongmin and Zhang Qi et al. extract text features from refutation posts, analyze the sentiment orientation of popular comments, verify the effectiveness of the REI (Refutation Effectiveness Index) for evaluating refutation effectiveness, and establish four regression models to provide decision-making suggestions for organizing refutation information in different scenarios [7]. Lü Tu and Chen Hao et al. clarify the group propagation process of online rumors through examples, reveal the governance effects and action pathways of refutation and deterrence mechanisms, and thereby enhance information governance capabilities [8]. Current research on factors influencing social network rumor refutation effectiveness remains relatively limited.

This study addresses three research questions: (1) What are the influencing factors of social network rumor refutation effectiveness in public health emergencies? (2) What are the pathways of influence among these factors? (3) What governance strategies exist for online rumors in public health emergencies? Using grounded theory and the COVID-19 pandemic as a case study, this paper analyzes influencing factors, constructs a model of factors affecting online rumor refutation effectiveness, and proposes corresponding governance strategies to provide decision-making references and effectively avoid social risks.

2. Related Concepts and Literature

2.1 Online Rumors and Social Impact

Rumors typically refer to "unsubstantiated information" spread through various channels. Some scholars define rumors as unverified explanations or analyses of events transmitted among groups concerning issues of public concern [9]. Rumors exist in various events, particularly those involving personal safety and catastrophic consequences [10]. Online rumors are unverified events or issues disseminated through online media to achieve specific propagation or fact-concealing purposes, while the public lacks definitive information and knowledge to verify them [11]. Online rumor propagation is influenced by user behavior, psychological factors, and refutation information [12].

The global COVID-19 pandemic has prompted scholars across fields to consider scientific responses to public health emergencies, during which rumor propaga-

tion becomes more severe [13], disrupting online order, triggering public panic, exacerbating social conflicts, and threatening social stability. Rumors exist during "information vacuum" periods when official information is delayed relative to events [10]. Rumor propagation misleads judgment, affects economic development [12], and can cause political consequences [14]. Even after rumors subside, risks may not completely dissipate, leaving potential secondary risks [15].

2.2 Refutation and Refutation Effectiveness

Refutation refers to using solid evidence to counter and correct rumors after their propagation to reduce negative impacts [16-17], making appropriate refutation strategies crucial for addressing potential risks. The two main refutation approaches are preventing rumor spread and explaining facts to clarify rumors [14]. Some research classifies basic types of online rumor spread in emergencies as copy-type, transformation-type, and compound-type, employing delay, suppression, hedging, and combination strategies to curb rumor spread [18].

Refutation effectiveness refers to public acceptance of refutation information—the degree to which people realize previously received information was false and believe the refutation. Based on relevant literature, this study defines refutation effectiveness as whether the public believes refutation information received through various channels and clearly understands that pre-refutation information was false. Some studies construct appropriate refutation effectiveness indices to identify key influencing factors and provide decision-making suggestions for platforms [14]. Others build user information behavior game models considering questioning effects, analyzing constraints for optimal refutation effectiveness and simulating parameters to provide suggestions for improving refutation information propagation [19].

2.3 Proposed Factors for Public Health Emergency Refutation Effectiveness

Against the backdrop of frequent online rumors, public health emergencies attract significant attention, with such rumors more likely to trigger social panic and severely affect stability. Since COVID-19 emerged, related online public opinion has caused disorder in cyberspace, with rumors about the pandemic emerging continuously, pseudoscientific claims flooding online public spaces, and online fraud incidents occurring frequently. The public struggles to distinguish truth from falsehood amid massive information, with tension and anxiety intensifying and online public opinion fluctuations showing polarization trends. Additionally, hostile forces maliciously amplify controversial topics, attempting to disrupt domestic online public opinion order, making cyberspace governance urgent [20]. How to refute rumors quickly and effectively is a pressing problem.

To analyze influencing factors and action pathways of refutation effectiveness in public health emergencies, this study conducted semi-structured interviews to obtain rich interview records for factor and pathway analysis. Through contin-

uous comparison and concept extraction, categories and theories were formed to objectively and deeply analyze characteristics and pathways of influencing factors during public health emergencies.

3. Research Design

3.1 Research Design

The research process was divided into three stages: preliminary preparation, data processing, and theory formation. First, in the preliminary stage, research questions were proposed through phenomenon observation, and a semi-structured interview outline was developed after literature review. After briefing respondents, formal interviews were recorded to complete data collection. Second, in the data processing stage, Tencent AI's speech recognition function converted recordings to text. NVivo 12.0 software was used for text analysis, as it assists researchers in collecting, organizing, analyzing, and presenting textual data, enhancing qualitative research rigor and credibility [21]. The software performed three-level coding on textual materials. Third, in the theory formation stage, the software coding yielded influencing factors for refutation effectiveness during public health emergencies using COVID-19 rumors as examples. Based on initial theory construction, saturation testing produced a theoretical framework, and MATLAB matrix analysis of factor categories determined category matrices and interpretive structural models. The research design flow is shown in Figure 1 [Figure 1: see original paper].

This study adopts grounded theory analysis, which includes open coding, axial coding, and selective coding. Compared with other methods, grounded theory typically examines social phenomena and current social problems through continuous abstraction and high-level generalization, ultimately producing testable theoretical models through scientific, standardized coding [22]. This method builds theory from empirical data rather than testing research hypotheses through existing theory [23], enabling targeted interview questions based on actual research contexts to obtain the most relevant results and ensure research quality.

Literature analysis reveals that previous rumor and refutation effectiveness research mostly used quantitative methods like regression equations based on existing theoretical models to explore refutation rationality. However, these quantitative methods haven't comprehensively and thoroughly analyzed rumor propagation factors from the root, whereas grounded theory is highly practical for exploring "what" and "why" questions. Therefore, this study selected grounded theory, starting from the public's actual experience with COVID-19 rumors and refutation effectiveness, to more effectively and comprehensively explore influencing factors during public health emergencies.

3.2 Research Sample

Sample selection directly affects interview quality. To ensure interview data could effectively address research questions, two principles guided sample selection: First, respondents must be users who understood COVID-19 rumors and refutation phenomena and continuously followed related events. Second, respondents should have experience believing rumors during public health emergencies and some understanding of refutation. After preliminary surveys, 13 respondents were selected. These individuals had experienced believing rumors during public health emergencies and had deeper insights into receiving refutation information and its effectiveness, making them representative. Table 1 shows basic respondent information.

Respondents' gender, education, occupation, birthplace, and region were relatively randomly distributed, avoiding potential bias from homogeneous sampling.

3.3 Interview Data Collection

Using COVID-19 online rumors as examples, this study conducted semi-structured interviews with representative public groups to obtain first-hand data. The interview outline was developed based on literature review and adjusted during interviews according to responses to ensure comprehensiveness. Interviews included online voice and face-to-face formats, each lasting 15-30 minutes. All interviews were recorded and saved, then converted to text for analysis [24].

The interview process covered COVID-19 rumor refutation and effectiveness, including rumors such as: Academician Zhong Nanshan being infected, 5G antennas in masks, hospital patients escaping, and claims that Banlangen and Shuanghuanglian could treat COVID-19. The interview outline included: (1) Age, gender, education, region, rumor-believing history; (2) Knowledge of COVID-19 rumors; (3) Initial reactions upon encountering rumors; (4) Reasons for believing or not believing rumors; (5) Types of refutation information deemed trustworthy; (6) Intentions after receiving refutation; (7) Additional comments on COVID-19 rumors and refutation. Before formal interviews, researchers contacted each respondent to explain the study, ensuring understanding and scheduling. During interviews, question phrasing was adjusted as needed to ensure comprehension and obtain accurate, effective results.

4. Influencing Factors Analysis

4.1 Open Coding

Interview recordings were converted to text and coded line-by-line using NVivo 12.0 to extract the most important and frequently occurring original statements for initial conceptualization. Using a frequency threshold of 3 occurrences, initial

concepts appearing 3 or more times were merged and categorized. This yielded 22 initial concepts categorized into 12 categories, shown in Table 2 .

4.2 Axial Coding

This study integrated the 12 categories from open coding into 6 main categories: refuter, refutation audience, information content, release timing, presentation format, and channel type. These were further summarized into three dimensions: subject, information, and channel, as shown in Table 3 .

4.3 Selective Coding

As the third step in grounded theory, selective coding aims to refine and integrate categories from axial coding and establish relationships between core and other categories [24]. By comparing the 6 main categories, this study revealed structural relationships among them, as shown in Table 4 . Grounded theory results indicate that subject, information, and channel factors for COVID-19 public health emergencies interact and influence refutation effectiveness. The most direct influences come from refuter, audience, information content, and presentation format, while release timing and channel type have indirect effects. Different release times accompany varying rumor propagation levels and public acceptance, indirectly affecting effectiveness, while channel type indirectly influences effectiveness by reflecting the refuter.

4.4 Theoretical Saturation and Validity Testing

Theoretical saturation testing ensures coding comprehensiveness and subsequent research rationality. Before formal coding, 13 respondents were randomly divided into a research group (10 people) and validation group (3 people). After coding both groups' interview data separately, the validation group's coding results revealed no new categories beyond those in the research group, indicating conceptual saturation.

Descriptive validity testing refers to accuracy in describing external phenomena, requiring two conditions: describing concrete, observable phenomena [26]. To ensure descriptive validity, interviews were recorded and converted to text for coding. Tencent AI's speech recognition platform was used for automatic speech-to-text conversion, combined with manual verification to ensure text accuracy matched respondents' speech patterns.

Theoretical validity testing examines whether research-based theory authentically reflects studied phenomena. This study satisfies theoretical validity: before interviews, researchers explained the study's content and significance to ensure respondents' understanding, guaranteeing interview validity and authenticity. Additionally, a well-designed grounded theory outline and strict three-level coding using NVivo 12.0 ensured coding result validity.

Interpretive validity testing assesses researchers' ability to understand and reproduce respondents' meaning. To better comprehend respondents' expressions, this study: (1) asked for clarification when statements were ambiguous during interviews to ensure mutual understanding; (2) used automatic speech recognition with manual verification during text conversion to maintain respondents' speaking patterns.

4.5 Influencing Factors SIC Model

Through the three grounded theory steps, this study obtained 22 initial concepts, 12 categories, 6 main categories, and 3 dimensions. The subject dimension includes refuter and refutation audience. The refuter comprises government, experts, and relatives/friends who publish refutation information. The refutation audience comprises receivers whose cognitive levels and negative emotions during the pandemic affect refutation effectiveness. Both are key influencing factors. The information dimension forms the foundation of refutation effectiveness, explaining how information content, release timing, and presentation format affect outcomes. The channel dimension includes central media, refutation platforms, and online media, reflecting platforms where refuters publish and audiences receive information.

Based on grounded theory results, this study constructed a public health emergency online rumor refutation effectiveness influencing factors model integrating subject, information, and channel dimensions, as shown in Figure 2 [Figure 2: see original paper]. This SIC (Subject, Information, Channel) model shows these three factors interact and influence refutation effectiveness. Better refutation effectiveness means audiences believe the information more and are willing to refute for others, becoming new refutation information disseminators and creating a positive cycle.

4.6 Interpretive Structural Model Equation Construction

Interpretive Structural Modeling (ISM) is a structured modeling technique based on directed graphs and matrix theory that decomposes complex systems into multi-level hierarchical structure models [27]. It is a systems analysis method that clarifies seemingly chaotic relationships among system elements to find internal logical connections [28]. This study constructs an interpretive structural relationship among influencing factors through the following steps: adjacency matrix A $\rightarrow$ reachability matrix M $\rightarrow$ hierarchical structure model $\rightarrow$ interpretive structural model [29].

Based on grounded theory coding results, this study identified 12 influencing factors and collected respondent feedback. If respondents believed factor i directly influenced factor j, it was marked as 1; otherwise 0. Factors marked as 1 by five or more respondents were finalized as 1, others as 0. These results established logical relationships among factors, constructing a 12\$×\$12 adjacency matrix A where aij = 1 indicates direct influence from factor Si to Sj, and aij

= 0 indicates no direct influence.

Adjacency matrix A only shows direct relationships. Therefore, matrix operations were performed to obtain reachability matrix M, representing both direct and indirect relationships. Using MATLAB, (A+I) was repeatedly calculated until (A+I)^(k-1) ≠ (A+I)^k = (A+I)^(k+1), yielding M = (A+I)^(k+1), where I is the identity matrix and k = 1, 2, 3, … Reachability matrix M shows direct and indirect influences among factors a1-a12 and their transitivity [28], as shown in Table 5 .

Based on matrix M, relationships among the 12 factors were clarified and divided into different levels to establish the interpretive structural model. In the matrix, the set of factors where elements in row i equal 1 is R(ai), the reachable set of factor ai. The set where elements in column i equal 1 is Q(ai), the antecedent set [29], as shown in Table 6 .

Based on R(ai) Q(ai), factors were divided into three hierarchical levels. “Timeliness” and “Multimedia Information” constitute the first level (foundational layer). “Government,” “Experts,” “Central Media,” “Online Media,” “Refutation Platform,” “Negative Emotions,” “Clarifying Facts,” and “Refuting Rumors” form the second level (regulatory layer). “Cognitive Level” and “Relatives/Friends” occupy the third level (functional layer), as shown in Figure 3 [Figure 3: see original paper].

5. Discussion Analysis

5.1 Influencing Factors Analysis

Through the three-step grounded theory process (open, axial, and selective coding), this study gradually integrated and summarized a refutation effectiveness influencing factors model comprising three dimensions: subject, information, and channel. The model includes six main categories: refuter, refutation audience, information content, release timing, presentation format, and channel type. According to the SIC model framework, refutation effectiveness in public health emergencies can be improved through these three dimensions.

Regarding the subject dimension, refuter credibility and authority are crucial. During public health emergencies, authoritative officials or experts should be selected as refuters to minimize rumor propagation scope and negative impact as quickly as possible. The refutation audience’s cognitive level also matters, and negative emotions cannot be ignored. Therefore, public cognitive levels should be enhanced to better identify and prevent rumor spread, while negative emotions during information vacuum periods should be addressed promptly to avoid unnecessary impacts.

Regarding the information dimension, refutation information content, release timing, and format significantly affect effectiveness. Information must be authentic, well-founded, and targeted at rumor vulnerabilities, using photos, videos, and text to enhance credibility. The uncertainty of emergencies and

public urgency for authentic information require timely information disclosure to avoid lag and ensure refutation timeliness.

Regarding the channel dimension, the type of channel publishing refutation information plays a key role, affecting information reception and thus refutation effectiveness. Trusted official media channels should be selected to ensure information quality, while multi-channel dissemination should be guaranteed. For vulnerable groups like the elderly, refutation information should be strengthened in traditional channels to ensure efficient and widespread propagation, better addressing negative impacts and avoiding social risks.

5.2 Action Pathway Analysis

To improve refutation effectiveness, this study analyzed action pathways based on influencing factor analysis. All six main categories directly or indirectly affect refutation effectiveness, and understanding their pathways is crucial for improvement.

From the subject dimension, refuters (government, experts, relatives/friends) represent credibility and authority, directly affecting refutation effectiveness. During emergencies, governments should strengthen information interaction with the public, build communication bridges among governments, experts, and citizens, respond to public demands, and guide rational discourse. Refutation audiences, as information receivers, are directly affected by their cognitive levels and negative emotions. Therefore, governments should actively perceive public demands, respond with facts, create cautious and calm public opinion environments, enhance public judgment, and shift from "blocking" to "guiding" to optimize refutation effectiveness [20].

From the information dimension, whether refutation information can restore truth and identify rumor vulnerabilities directly affects effectiveness. Presentation format—whether with photos, videos, and other multimedia—also directly affects perceived credibility. During public health emergencies, professional refutation sources should be selected with appropriate background introduction to enhance persuasiveness [17]. Release timing is also important, as rumor propagation and public attention change over time, indirectly affecting refutation effectiveness.

From the channel dimension, whether refutation information is published on official channels or online media affects public trust based on the publisher's credibility, thus indirectly influencing effectiveness. Due to social media's derivative propagation characteristics (forwarding and commenting continuously update topics, causing users who participated in discussions to receive related information again and extending rumor lifespans), periodic refutation information release through different channels can minimize negative impacts [31]. Additionally, public opinion control agencies, web portals, and self-media platforms need to cultivate talent to differentiate information usage behaviors and preferences across different populations, achieving refined refutation information delivery

through big data analysis [31-32].

Compared with previous studies on non-emergency refutation effectiveness that only examined content and text features, and evaluated effectiveness solely through forwarding and comment numbers [30], this study considers subject, object, and channel dimensions for a multi-dimensional analysis of factors affecting refutation effectiveness during public health emergencies.

5.3 Hierarchical Relationship Analysis

For more comprehensive and detailed results, this study further explored relationships among factors based on coding results, constructing a hierarchical structural model that examines influencing factors from three layers: foundational, regulatory, and functional.

Foundational Layer Analysis: The most critical factors are refutation information timeliness and multimedia presentation. These foundational factors influence the functional layer through the regulatory layer or directly affect it, demonstrating the fundamental role of refutation information itself. Therefore, during public health emergencies, ensuring information authenticity and quality while using optimal presentation methods during the "golden refutation period" fundamentally guarantees effectiveness improvement.

Regulatory Layer Analysis: Eight factors at this layer play intermediate regulatory roles. Among them, central media, government, and experts influence five other regulatory layer factors, highlighting the importance of official credibility. Both refuter and channel aspects require improvement. Additionally, "clarifying facts" and "refuting rumors" as two information content types influence multiple factors, showing information content's significant role. Therefore, refutation information should restore truth and identify errors to enhance credibility and quality.

Functional Layer Analysis: Public cognitive level and relatives/friends as refuters occupy the functional layer, influenced by other factors. Therefore, during emergencies, targeted improvement strategies based on other factors' changes can simultaneously enhance public cognitive levels and relatives/friends' credibility as refuters, making the public more likely to believe facts and improving refutation effectiveness.

6. Research Conclusions

Theoretically, this study constructed the SIC model analysis framework comprising subject, information, and channel dimensions through grounded theory coding. It analyzed influencing factors and pathways affecting refutation effectiveness in public health emergencies. Using ISM and MATLAB matrices, the study constructed a hierarchical structural model to further examine factor relationships. Practically, based on the SIC framework, the study analyzed the practical significance and guidance of action pathways and hierarchical structures,

proposing governance strategies for social risks in public health emergencies to provide reference for effectively addressing future rumor problems.

This study has limitations. The number of interview respondents was limited, and age distribution was relatively homogeneous. Future research will expand sample size for more accurate results. Additionally, this study only examined qualitative relationships among influencing factors, requiring future quantitative analysis and simulation studies.

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A Study on the Factors Influencing Online Rumor Refutation Effectiveness in Public Health Emergencies — A Case Study of Online

Rumors During the COVID-19 Pandemic

Wang Xiwei, Qiu Chengcheng, Jia Ruonan

Abstract: [Purpose/significance] During public health emergencies, online rumors have serious negative effects and disrupt social order. Taking the COVID-19 pandemic as an example, this paper explores the factors influencing online rumor refutation effectiveness to provide references for decision-making, thereby effectively avoiding social risks. [Method/process] Using grounded theory, this study explores influencing factors of refutation effectiveness, obtaining 22 initial concepts, 12 categories, and 6 main categories. Based on these, interpretive structural modeling and MATLAB matrix analysis examine relationships among factors. [Result/conclusion] Coding results summarize influencing factors into three dimensions: subject, information, and channel. The SIC model analysis framework is constructed to analyze main categories' pathways to refutation effectiveness, building a hierarchical structural model dividing factors into foundational, regulatory, and functional layers.

Keywords: public health emergency; online rumor; rumor refutation effectiveness; influencing factor

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