

Emotional Evaluation of Digital Governance Technologies by Social Media Users: A Case Study of the Health Code*

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Abstract: The Health Code represents a significant advancement in digital anti-epidemic efforts, with its technological dimension enhancing governance efficacy. It is essential to assess the perceived value for the target audience. This study focused on the Health Code, extracted Weibo posts from 2020 to 2022, employed Snow NLP and Baidu Senta for sentiment analysis, and implemented latent Dirichlet allocation topic modeling. The findings indicated that both public and official accounts exhibited a neutral to positively biased sentiment in public posts, with comments showing a positive correlation. The sentiment distribution in comments exhibited greater variability than that in posts. Regarding sentiment topics, popular discourse indicated support for the health-code system, whereas official discussions emphasized its rapid emergency roll-out. This study provides a research sample to elucidate the significance and value of digital governance technology in emergency management processes.

Keywords: Health Code, Digital Governance, Weibo, Emotional Expression, COVID-19

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Introduction

The COVID-19 pandemic has posed considerable challenges to social governance globally. The inherent contradictions between pandemic control and social–economic development, while mitigating the adverse impacts of the epidemic, have emerged as a significant global concern. Past anti-pandemic practices have demonstrated that employing technologically advanced methods and incorporating digital governance technologies, such as big data and artificial intelligence, to establish an intelligent pandemic prevention model, are critical measures in addressing the COVID-19 outbreak (Budd et al., 2020). The “Health Code (a China-specific digital pandemic governance system)” has been instrumental in pandemic control and is recognized as an effective prevention tool in digital anti-pandemic initiatives. For governments, the Health Code can substantially enhance the efficiency and accuracy of personnel information verification. For individuals, the Health Code mitigates the danger of infection due to crowd assemblies. The Health Code facilitates employee management in businesses. The “Statistical Report on Internet Development in China” published by the China Internet Network Information Center (CNNIC) in 2021 indicates that nearly 900 million individuals have applied for the “health code for epidemic prevention” through the national integrated government service platform. Utilization has exceeded 40 billion instances, facilitating “one code access” in most areas of the country and highlighting the key role of big data (CNNIC, 2021).

This study employed Python to collect posts and comments related to the Health Code on Weibo from January 2020 to December 2022. Analyzing and summarizing this data facilitated a deeper comprehension of social media users’ emotional expressions and evaluations of the Health Code as a digital governance tool.

This section serves as the introduction. The second section examines the research status of digital governance technology during the pandemic, specifically the Health Code, and delineates the research questions. The third section elucidates the methodologies employed, encompassing Snow NLP for sentiment analysis, Baidu’s sentiment analysis library, and latent Dirichlet allocation (LDA) for topic modeling. The fourth section articulates the analysis results. The fifth section explores the similarities

and differences in Weibo users' emotional expressions regarding the Health Code and their reasons. The final section concludes the paper.

Literature Review

Social Identity in Medicalization

Social identity is a component of an individual's self-concept and originates from the recognition of belonging to relevant social groupings (Reimer et al., 2022). In the mediatized context of network societies, digital spaces and simulated environments serve as the principal domains of information and existence for audiences, substantially impacting public social cognition, interpersonal interactions, and relationship coordination (Wu, 2018). In social networks, collective activities foster group immersion and anonymity, enhancing the salience of group identity and, consequently, the impact of mutually recognized groups and their norms (Benjamin et al., 2015). Moreover, social trust and network density on social media platforms significantly influence members' social identities, while the use of shared language on these networks enhances social identity (Wang et al., 2022). Social identification theory is associated with digital governance practices—a connection that is apparent in users' emotional responses toward digital governance tools like the Health Code. The social identification group's classification mechanism encourages Health Code users to categorize themselves based on their experiences, while group comparisons intensify attitude polarization. Supporters perceive it as efficient governance, whereas opponents emphasize inconvenience and risks, highlighting varied emotional responses.

Digital Governance Embedded in COVID-19 Control

In the informationalized society paradigm, data and information are essential to social existence and public governance, rendering the advancement of digital governance a global trend and offering novel solutions for addressing diverse, complex public issues (Milakovich, 2012). The concept of digital governance originates from the simultaneous advancement of information technology and consideration

of new public management, enhancing its content through dynamic and transparent interactions between society and technology (Dawes, 2009; Dunleavy et al., 2005). As digital governance practices proliferate worldwide, studies encapsulating experiences across diverse domains, including government–business relations (Arendsen et al., 2014), corruption governance (Lio et al., 2011), and public services (Francis & Ricardo, 2022), continue to enrich the discipline.

Simultaneously, the “digital divide” constitutes a significant obstacle to digital governance, manifesting as disparities in digital technology applications and the development of the digital economy across various groups (Liao et al., 2022). Research in digital governance should aim to bridge the digital divide and promote public engagement in digital governance. Additionally, it is essential to emphasize the objectives of information technology, safeguard personal data, and uphold the rule of law to balance data surveillance authorities (Okun et al., 2023).

Digital technologies, including cloud computing, artificial intelligence, and blockchain, are instrumental (Yassine & Shah, 2020). Governments worldwide have developed various mobile applications for symptom self-management, home monitoring, and risk assessment (Kondylakis et al., 2020). Examples include public health education tools (Maxime & Lorenz, 2020), Dutch e-health support technologies (Timmers et al., 2020), and British technology for COVID-19 monitoring (Brainard et al., 2023). However, these applications are limited by smartphone ownership, user trust, and accessibility (Michael et al., 2020). Researchers have examined the impact of application usage (e.g., installation and use) on sociopsychological impediments (e.g., citizens’ lack of prosocial attitudes, concerns about safety and privacy, and inadequate perception of infection risks); this has led to diminished perceived benefits post-usage (Altmann et al., 2020; Munzert et al., 2021).

Health Code: Uses and Controversies

The “Health Code,” now a historical artifact, exemplifies the developmental trajectory of original innovation and re-innovation within digital governance systems. Contemporary research on the Health Code emphasizes its functionality and the associated rights and interests. Health Code functionality has been upgraded, reinvented, and modernized.

From a management perspective, the Health Code serves as a form of social infrastructure, repurposing existing data systems to avert public infractions of pandemic control measures and correcting individual conduct according to optimal standards (Sun & Wang, 2022). In daily life, the Health Code assesses individuals' infection risks by considering their travel history, length of stay in high-risk places, and relationships with potential carriers (Liang, 2020; Zhou et al., 2021). In medical settings, triage systems founded on the Health Code have demonstrated significant effectiveness and efficiency in triaging patients with an epidemiological history (Chen et al., 2021).

Rights and privacy concerns associated with the Health Code are subjects of academic debate and contention. "Behind all intelligence lies surveillance and control" (Ryan, 2020), as intelligence is predicated on data, which encompass every individual's fundamental rights and interests. The implementation of the Health Code was an urgent measure by government entities to mitigate and manage the COVID-19 pandemic. The aggregation and storage of data from the Health Code heightened the dangers of personal data leakage and misuse, raising concerns about individual privacy (Ning et al., 2020; Shen & Wang, 2021). Consequently, it is essential to elucidate and standardize the powers of modifying Health Code statuses, regulations, and conversion procedures; moreover, capricious status alterations must be deterred and sanctioned, and legal recourse must be provided for individuals harmed by erroneous status modification in anticipation of future public health crises (Shen & Wang, 2023). Researchers like Huang (2022) contended that users perceive the convenience of the Health Code, trust in the government, and the government's purpose in managing Health Code data, thus believing that their privacy rights are protected while using the application. This perception is influenced by the public's subjective view of digital governance technologies in traditional and emergency scenarios and is affected by the technology's quality and the credibility of the organizations behind it (Duan & Deng, 2022).

This study monitored and gathered Weibo posts concerning the Health Code from 2020 to 2022, emphasizing public and official posts and comments. This study investigated the following concerns through sentiment and thematic analyses:

- (1) Emotional evaluation of digital governance technologies related

to the Health Code by social media users in their posts and comments.

- (2) The evolution of the spectrum of emotions conveyed by social media users in posts and comments.
- (3) The similarities and variances in the topics addressed, contingent upon the diverse emotions articulated by social media users.

Methods

Web crawling techniques were employed to collect Weibo posts from 2020 to 2022. This study utilized Baidu Senta and Snow NLP methodologies for the sentiment analysis. LDA topic modeling was used to analyze the topics under different emotional categories.

Data Collection

Python was used to collect data on posts and comments related to the Health Code from Weibo between January 2020 and December 2022. This study aimed to enhance the comprehension of the topics discussed and the emotional expressions associated with the Health Code by analyzing and summarizing the post data. The main steps were as follows.

First, between December 2022 and January 2023, Python was employed to scrape posts and comments from Weibo from 2020 to 2022 using keywords such as “health code,” “red code,” “yellow code,” and “green code.” A total of 545,811 posts were amassed, comprising 462,940 posts and 79,396 comments from the public and 82,871 posts and 20,962 comments from officially verified users.

Second, relevant information, including post content, posting time, and verification type (e.g., personal, corporate, and government verification), was extracted from social media users’ posts. JSONPath was employed to parse the data fields, and an appropriate data structure was established to store this information.

Third, the extracted posts and data were recorded and stored in a database.

Data Preprocessing

The post data collected using Python was rife with extraneous elements, including noncharacter lists, whitespace, punctuation, and non-Chinese lexicon, necessitating a cleaning process. The Jieba module in Python was employed to eliminate stop words during the word segmentation process, thereby filtering out content with ambiguous or contradicting emotional expressions, such as “one,” “all,” and “everything.” The segmentation results were then reviewed. Subsequently, data deduplication was executed by contrasting the unique identifiers or key fields inside the database. Missing or anomalous values in the database were substituted or eliminated. Finally, the processed data were standardized into a consistent format for further processing and analysis.

Baidu Senta Sentiment Analysis

This study employed Baidu’s natural language processing technology—the Baidu Senta sentiment analysis system—to analyze emotional tendencies and extract viewpoints from comments. This deep learning-based system autonomously acquires deep semantic and syntactic features and demonstrates significant generalization capabilities, even with relatively long texts. The sentiment tendency analysis, involving the direct detection of emotions in everyday communication texts, can automatically discern primary and secondary sentiment categories expressed by current conversationalists, along with their confidence levels, thereby supporting applications such as topic monitoring and public opinion analysis. Primary sentiments were categorized as positive, neutral, and negative; secondary sentiments used for this study encompassed positive (e.g., happiness) and negative (e.g., anger, disgust, fear, and sadness) emotions. For comments, a perspective extraction interface for Weibo posts was utilized to extract focal points and viewpoints from comment phrases, subsequently outputting the associated tags and polarity of these opinions.

Snow NLP Sentiment Analysis

Sentiment analysis, a technique extensively applied in social media

data analysis, is fundamentally categorized into dictionary- and machine learning-based methodologies. Certain studies have also used third-party libraries developed for sentiment analysis, such as Snow NLP, which has been applied to opinion analysis contexts on social media and has demonstrated superior performance. Therefore, this study designated Snow NLP as the sentiment analysis tool. Snow NLP was specifically engineered for the processing of Chinese text, providing a distinct advantage in Chinese sentiment analysis and resulting in its widespread application in social media sentiment analysis. In Snow NLP, the Chinese text was input into the module, which subsequently examined the words in the text for correspondence in the sentiment lexicon. Upon identifying a match, the emotional inclination of the words was assessed, and the frequency of positive and negative sentiment words in the text was quantified to derive the text's sentiment scores. The sentiment scores spanned from 0 to 1, where values nearing 1 signified a more pronounced positive emotion and those approaching 0 denoted a more apparent negative emotion.

LDA Topic Modeling

Topic modeling is a text analysis technique developed to uncover hidden information in extensive text datasets. It uses LDA, proposed by BLEI et al. in 2003, and has been widely applied in text mining. Various topics within a document are selected using a probabilistic model where words associated with a topic are determined by the topic's probability distribution over words. The LDA topic model allows for the adjustment of the number of topics by utilizing the topic consistency score provided by the Gensim library in Python, thereby determining the optimal number of topics based on the highest topic consistency score. Thus, in this study, each emotional category was analyzed through three to five topics to elucidate the themes of emotional expression among social media users.

Results

Data Distribution of Social Media Platform Posting

On February 29, 2020, China's National Public Service Platform

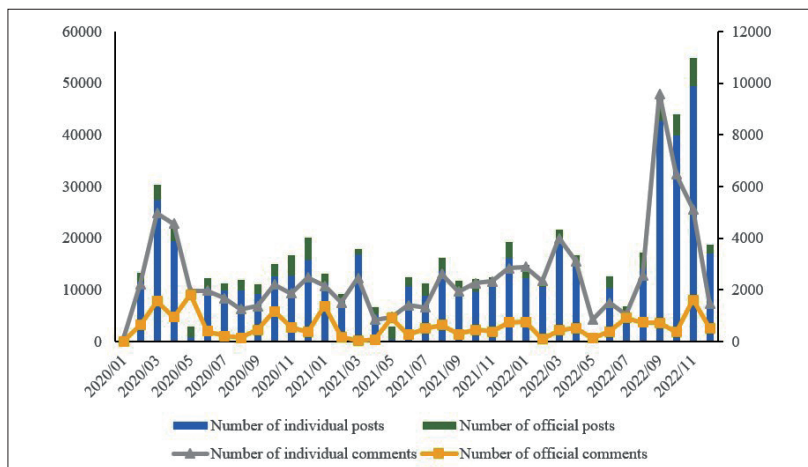


Figure 1. Number of Posts and Comments

launched the “Health Information Code for Epidemic Prevention” to facilitate the systematic governance of a “mobile” society. Three years of anti-epidemic practices across various Chinese regions have demonstrated that implementing the Health Code facilitated the resumption of work and production and ensured the safety and orderly conduct of daily lives for the populace. The statistical analysis of posts and comments concerning the Health Code on Weibo (Figure 1) revealed a variable pattern from 2020 to 2022. Discussion peaks were observed in February and March 2020, as the Health Code transitioned from pilot projects in individual provinces and cities to official implementations throughout various regions, generating considerable public attention. Owing to recurrent outbreaks and adjustments in epidemic prevention measures, discussions regarding the Health Code as a digital governance technology have continually fluctuated on social media platforms. The peak period occurred from September to November 2022, propelled by intense outbreaks in various regions of China and the necessity for continuous nucleic acid testing and health reporting. This resulted in heightened Health Code utilization and significantly elevated discussion volumes relative to other intervals. The accessibility of data collection resulted in public posts comprising the highest proportion, with official posts and

public comments being close in number, while official comments were the least prevalent. This indicates the public's propensity to provide timely feedback and expression while utilizing the Health Code.

Sentiment Analysis Results

The sentiment scores were computed via the Snow NLP sentiment analysis by analyzing the data across four dimensions: public posts, comments on public posts, official posts, and comments on official posts. The emotional tendencies of various entities were compared across posts and comments. Comments on public and official posts encompassed diverse user groups, with public comments comprising the majority. The sentiment distribution for public posts, comments on public posts, official posts, and comments on official posts is graphically represented (Figure 2).

The average sentiment score across four dimensions varied marginally between 0.43 and 0.67, typically indicating a neutral to positive emotional expression. The sentiment scores for public posts ranged from 0.39 to 0.67, averaging 0.48. Meanwhile, the scores for comments on public posts ranged from 0.5 to 0.76, with an average of 0.62, consistently exhibiting higher sentiment scores than public posts at corresponding time intervals. A regression analysis of public posts and comments yielded an R -value of 0.4, indicating a positive correlation between the sentiments expressed in public posts and comments, accompanied by an F -value of 0.014, suggesting a robust regression model. This indicates that the sentiment in public comments varied in accordance with the sentiment of public posts, with an elevated sentiment in public posts leading to a higher sentiment in comments.

The fluctuations and amplitudes of sentiments in official posts and accompanying comments were more significant than those in public posts. The sentiment scores for official posts ranged from 0.34 to 0.71, with an average of 0.49; for comments on official posts, the scores ranged from 0.43 to 0.77, with a mean of 0.54. The average sentiment score for comments on official posts exceeded that of the posts themselves; however, the broader variation range suggests a more complex interweaving and conflict of emotions across various groups. Some intervals were marked by considerable emotional discrepancies, indicating inconsistencies between the sentiments expressed in official

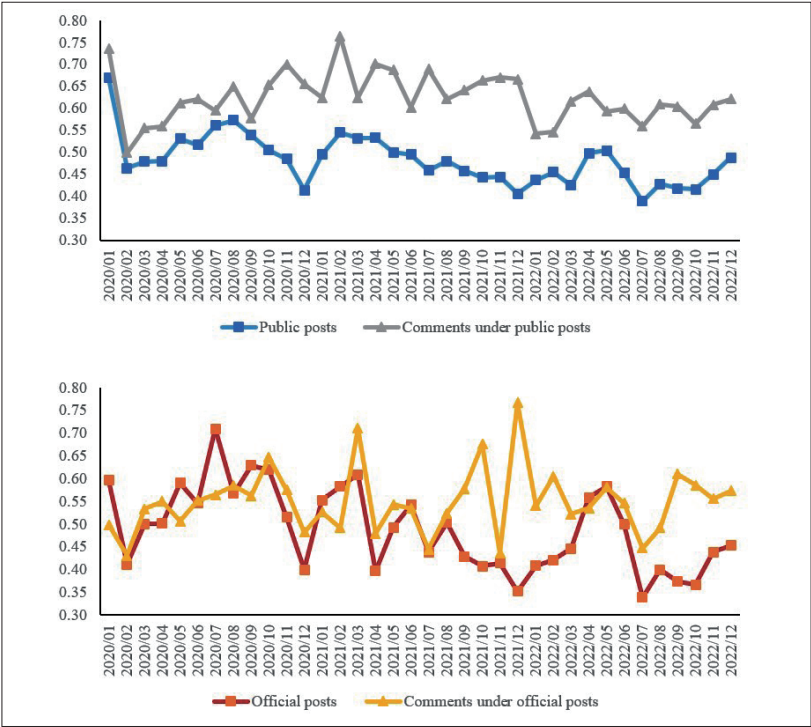


Figure 2. Social Media Users' Sentiment Scores

posts and the comments beneath them, leading to substantial emotional variations.

Additionally, a regression analysis of the sentiments in public and official posts yielded a coefficient of 0.798, indicating a strong positive correlation and alignment in emotional expressions, reflecting a relatively consistent emotional evaluation of certain topics. Furthermore, an analysis of sentiment scores revealed that the average ratings of comments on public posts were generally higher than those on official posts, indicating a higher overall emotional endorsement for opinions expressed in comments on public posts. However, within a few months, the sentiment scores for official posts increased.

In contrast to the sentiment analysis conducted with Snow NLP, the Baidu Senta sentiment analysis categorized the data into four

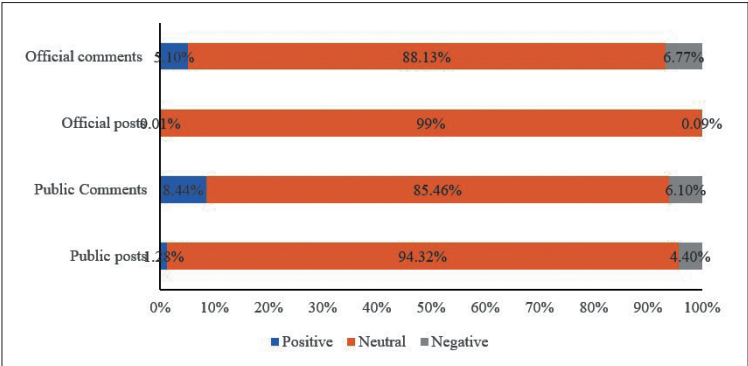


Figure 3. Sentiment Proportion of Various Entities

categories: public user posts, public user comments, official user posts, and official user comments. Numerous posts included duplicated reposts, which affected the results. Consequently, data consisting only of reposts or duplicated content were excluded, yielding the actual figures accessible for the sentiment analysis: 323,281 public posts, 79,396 public comments, 26,603 official posts, and 20,962 official comments. Based on the studied data, sentiments were classified into three primary categories: positive, neutral, and negative (Figure 3). Neutral sentiments dominated in both public and official posts and comments, aligning with the results of the Snow NLP sentiment score analyses. Neutral sentiments were more prevalent in public posts than in public comments, contrary to the higher sentiment scores for comments within public posts. Official posts demonstrated a 99% neutrality rate, indicating that the official media consistently upheld a neutral and impartial position in reporting on digital health technologies. Regarding comments from official users, approximately 88.13% were neutral, 5.1% were positive, and 6.77% were negative.

Topic Analysis Results

In the topic analysis, Baidu Senta sentiment analysis was used to classify the topics expressed by different entities based on their emotions. An examination of the original text corpus revealed that the expression

of positive and negative emotions in official posts and comments was limited and lacked thematic generalizability. Therefore, the analysis focused on neutral emotional expressions in official posts and comments. Given the extensive volume of public posts and comments across three years, December 9, 2020, was selected as the time point to separate the Health Code's progression into two periods: the development and evolution period and the nationwide unification period. This elucidates the thematic evolution of public and official emotional expressions across the two periods.

This study employed Python's Gensim library to calculate topic coherence scores for LDA topic modeling, ensuring the rationality of topic segmentation. Higher coherence scores indicated stronger keyword associations within a topic and clearer topic delineations. The results showed that the topic coherence score for official posts was 0.63, whereas that for public posts was 0.61, with both exceeding 0.5. This signifies that the chosen number of topics in this study was appropriate, and the extracted themes exhibited strong coherence and reliability.

Comparing the topics of official posts during these two stages, official media consistently emphasized the reporting of the COVID-19 pandemic's progression and the promotion and elucidation of epidemic preventive policies (Table 1). The Health Code, as a digital governance tool, has been leveraged to enhance the efficiency of pandemic control measures, and official media have utilized it as a channel for disseminating these measures. The topics encompassed the "Health Code Usage Guide" and associated functional announcements, including "Nucleic Acid Testing" and "Vaccine Administration" recommendations. There was an increased emphasis on pandemic-related information such as "Reports of New Confirmed Cases, Epidemic Prevention Measures, and Travel Tips." A comparative analysis of the two stages revealed that the first stage concentrated on interpreting and disseminating pandemic-related policies, whereas the second stage emphasized the implementation and enforcement of specific control measures. Despite the variation in themes over stages, there was continuity and adjustment in the control measures, hence preserving thematic consistency.

The public's emotional responses to the Health Code were diverse (Table 2). Regarding positive emotions, the public experienced the convenience of Health Code technology throughout the pandemic.

Table 1. Topics of Official Posts

Stage/Entity	Topic	Keywords
Official Posts of Stage One	New Confirmed Case Reports	confirmed cases, imported cases, asymptomatic, infected patients, quarantine, feverish individuals, masks, cough, medical observation, daily updates
	Health Code Usage Guide	Hangzhou, big data, application, upload, epidemic prevention, business, processing, information, service, economy
	Epidemic Prevention Measures	application, focus, home quarantine, community, risk control, command center, strict implementation, information management, collaboration, key locations
	Nucleic Acid Testing Requirements	appointment, negative COVID-19 PCR test proof, tested positive, testing location, hospital, school, time, flight, health certificate, every other day testing
	Travel Tips	public transport, tourist sites, tourists, examination, opening, body temperature, wearing masks, booking, personal protection, timely reporting
Official Posts of Stage Two	Nucleic Acid Testing and Verification	collaboration, sampling, designated areas, scheduled, arrangement, community, command center, students taking exams, announcement, staff
	Implementing Control Measures	personnel control, nucleic acid testing, lockdown management, testing, reducing gatherings, masks, home quarantine, timely reporting, high risk, negative COVID-19 PCR test proof
	Strengthening Prevention and Control Measures	key populations, key areas, life support, residential buildings, supplies, ensuring safety, new cases, report, centralized isolation, key industries
	Travelling Standards and Tips	booking, travel certificate, itinerary code, travel trajectory, information service, taking transport, citizens, proactive reporting, collaboration, timeliness
	Implementing Vaccine Administration	health barrier, encouragement and advocacy, street responsibility, community, vaccine information, elderly population, medical observation, active engagement, registration, medical staff

Possessing a green code facilitated seamless movement and permitted the resumption of normal activities in production and entertainment amid the pandemic's normalization. The "Health Code functionality

Table 2. Topics of Public Posts

Emotion	Phrase	Topic	Keywords
Positive	Phase One	Entertainment Activities	Celebrity following, travel, movie-going, video, music, anticipation, joy, humor, going out, friends
		Mutual Recognition and Interconnectivity	Beijing-Tianjin-Hebei, going out, displaying, green code, smooth, convenience, transfer, inspection, announcement, interprovincial travel
		Daily Life Status	friends, gatherings, outings, lazy days, rest, streaming, eating, relaxing, missing, happy
		Health Code Feature Upgrades	travel, skin, profile frame, give a like, desire, convenience, tourism, integration, booking, multifunctional
		Smooth Travel	smooth, highway, scenic spots, residential areas, transit, metro transfers, queuing, time-saving, green code, hubs
	Phase Two	Health Code Golden Skin	golden frame, attractive, completion, vaccination, travel code, interesting, scanning, epidemic prevention, fun, green
		Successful Code Conversion	call, wait, test every other day, community reporting, travel history, turn green, gray, home quarantine, popup, disease control center
		Daily Life Status	recreation, freedom, relaxation, homecoming, normal off duty, green code, clocking in, binge-watching, internet, encouragement
		Epidemic Containment	lifting lockdowns, free entry/exit, residential areas, gratitude, volunteers, joint efforts, turn green, nucleic acid, wait, passage
		Nucleic Acid Testing Stickers	cute, stickers, distribution, queuing, nucleic acid testing, Terracotta Army, fun, colors, volunteers, receiving
Neutral	Phase One	Returning Home/School	exams, testing, health status, proof, students, schools, test reports, smart, pre-exam prep, campus
		Prevention Measures	showing, wearing masks, temperature checks, registration, booking, identity information, collaboration, safety measures, outings, epidemic
		Travel Scanning	smartphones, login, app, elderly, airport, filling information, proxy, not access to, usage frequency, optimization

Emotion	Phrase	Topic	Keywords
Neutral	Phase One	Epidemic Locations	regions, Shanghai, Wuhan, Xinjiang, Macau, non-essential outings, residential areas, confirmed cases, nucleic acid testing, risk
		Prevention Policies	travel policy, health commission, postgraduate entrance examination guide, inspection, press conference, mutual recognition, public places, pay attention to physical condition, one-code pass, service
	Phase Two	Health Code Status	yellow code, red code, popup, stay at home, epidemic, three days, exams, 24 hours, reporting, travel
		Vaccine Administration	booking, queuing, nucleic acid testing, medical observation, three times, vaccination complete, golden skin, inquiry, timing, application
		Routine Nucleic Acid Testing	travel arrangements, testing every other day, negative proof, work, venue code, notice, holding proof, citizens, scheduled, queuing
		Travel Reporting	plans, rebooking, travel history, airport inspections, traffic police, filling information, staff, delays, unable to board, inquiry
		Daily Life Status	daily repetition, travel, nucleic acid, news, self-protection, building cluster info, tags, reporting, metro, stockpiling
Negative	Phase One	School/Exam Disruptions	online classes, live streaming, online exams, civil service exams, end of term, worry, late, screening, smartphones
		Health Code Changes Color	red code, yellow code, restrictions, testing, gloom, app crashes, smartphones, waiting, time, stay at home
		Travel Disruptions	tested positive, temperature checks, stress, doubts, cumbersome, squares, queuing, samples, useless, controlled areas
		Commuting	metro, lockdown, can't reach office, late, caution line, delay, public places, anger, daily, tired
		Severe Epidemic Areas	local epidemic, confirmed cases, quantity, sadness, disappointment, mask, app crash, network, feedback, disinfection
	Phase Two	Increasing Epidemic Risk	sad emoji, perplexed, quarantine, yellow code, worry, anxiety, nucleic acid, personal protection, check app, arrangement

Emotion	Phrase	Topic	Keywords
Negative	Phase Two	Health Code Popups	gray, unusable, panic, nucleic acid testing, stay at home, inquiry, travel code, time-consuming, quarantine, red code
		Frequent Epidemics	angry expression, agitation, waiting, cellphone, yellow code, ongoing, coding, staying at home, residential community, reporting.
		Disrupted Travel Plans	masks, returning home, returning to school, disappointment, queuing, nucleic acid testing, last-minute notifications, incomprehension, inquiries, waiting
		Repetitively Indicating the Health Code	sole credential, smartphone, scanning QR codes, app, travel history, venue code, subway, inspection, exhaustion, system crashes

upgrade,” which integrated travel codes, nucleic acid testing, vaccination, and personal health information, reduced unnecessary data reporting to a degree, eliciting expressions of approval and other positive emotions from the public. Regarding neutral emotions, the public voiced apprehension about the evolving pandemic circumstances, adjustments to epidemic prevention policies, and associated measures. This effectively guaranteed that the Health Code did not change the status, facilitating the maintenance of a regular lifestyle. Additionally, this reflects the public’s vigilance for the pandemic, compliance with nucleic acid testing mandates, prompt reporting of travel, and accountability for personal health. Regarding negative emotions, the public expressed dissatisfaction with significant disruptions to daily life or unforeseen circumstances, such as abrupt outbreaks and alterations in Health Code status, which hindered normal travel. While the public valued the convenience of Health Code technology, its implementation as a certification mechanism at the entrances of public places enforced categorized management, limiting the scope of public activities. Overall, modifications in epidemic prevention policies influenced thematic differences in public emotional expression throughout stages. The initial phase saw the public frantically advocating for “mutual recognition and interoperability,” whereas the subsequent phase, marked by frequent outbreaks and the cumbersome

Table 3. Topics of Comments by Different Entities

Entity	Topic	Keywords
Official Comments	Epidemic Information	disease control center, alerts, timely attention, announcements, cases, reinfection, latest news, imported cases, sharing, prevention
	Popularization of Vaccine Science	appropriate age, protective effect, science education, sharing information, side effects, Xinhua News, observation, fever, rest, youth
	Medical Treatment	treatment, reports, negative nucleic acid test, designated hospital, notification, discharge, cumulative increase, personal protection, daily, medical staff
	Epidemic Locations	Chengdu, Changsha, same city, Kunming, Ningbo, Henan, cases, key areas, elderly, international
	Travel Advisories	Spring Festival, Ministry of Culture and Tourism, media, tips, nucleic acid proof, safety precautions, traffic control, travel, health guide, proper planning
Public Comments (Positive Emotions)	Epidemic Containment	anticipation, unlocking, free movement, building blocks, community, homecoming, convenience, no new cases, mobile phones, code conversion
	Daily Life State	school start, scenery, commuting, shopping, display, protection, mobile phone, practical, precision, location
	Entertainment Life	love, binge-watching, celebrities, offline activities, support, meeting, rest, dorm life, fun, short videos
	Smooth Travel	buying tickets, metro, riding, comfortable, freedom, happy, green code, reporting, waiting, quick
	Health Code Skins	attractive, thoughtful, golden, nucleic acid test, negative, laughing emoji, happy, envious, launch, local
Public Comments (Neutral Emotions)	Travel Arrangements	unlocking, waiting, notice, news, queuing for testing, green code, display, travel, vacation, protective items
	Nucleic Acid Testing	duration, yellow code, gray code, spatiotemporal overlap, SMS, testing location, risk, frequency, notice, distance
	Epidemic Areas	outbreak, Zhengzhou, Shanghai, Xi'an, unable to travel, lockdown, waiting, time, leaving, community
	Platform Consultation	community, street office, travel issues, home quarantine, requirements, duration, health monitoring, recovery, hospital, heat
	New Cases	sad emoji, subway, stay at home, puzzlement, mask, newly added, control measures, delayed school opening, announcement, news

Entity	Topic	Keywords
Public Comments (Negative Emotions)	Home Quarantine	bored, going crazy, irritable, blanket measures, disappointed, community demands, door-to-door testing, food, wanting to go out, announcement
	Health Code Changes	sudden, inexplicable, gray code, testing every other day, waiting, time-consuming, irritable, delayed, inconvenient, app crash
	Community Lockdown	supplies, queuing, volunteers, fatigue, traffic, building, stay at home, quarantine, work, shopping
	Daily Life State	daily, nucleic acid testing, queuing, yellow code, anxiety, insomnia, travel inconvenience, mask, alcohol spray, inquiry
	Frustrated Mood	irritation, helplessness, unclear, sad expression, lockdown, postponement, system crash, phone inquiry, layers of approval, waiting

process of code display, progressively diminished the public's positive image of the Health Code.

Analyzing the topics of comments from officials and the public revealed that official comments predominantly addressed public inquiries, emphasizing factual, rational, and objective responses without significant emotional bias. Therefore, this study did not classify the topics of official comments based on the various emotional types. Additionally, during thematic classification, the topics in the official comments were too dispersed and exhibited significant overlap between the two stages, leading to their integration without a stage-based classification.

The official comments (Table 3) addressed public concerns on the pandemic's progression, vaccine information, medical treatment alternatives, and travel advice, thereby mirroring public information needs. Official interactive comments can address certain issues and provide prompt "dialogues" with the public, potentially mitigating public anxiety and unease to some extent. The topics in public comments mirrored those in the original posts, suggesting a continuity of discourse or the public's propensity to comment and express opinions on posts that interest or resonate with them. Public comments revealed that daily life circumstances and the seamless use of the Health Code became major topics, including grievances over lockdowns and travel restrictions. However, the skins and frames incorporated in the Health Code became

popular topics among the public, with their entertainment features adding to the public's positive perception.

Discussion

The Health Code exemplified the successful implementation of innovative governance practices in response to the pandemic. The Health Code, as a digital governance technology, served a vital function in controlling COVID-19. Integrating the Health Code into the existing governance system for managing societal “mobility” facilitated real-time verification of individuals' health statuses, thereby balancing the resumption of work and production with quarantine and epidemic prevention. This study analyzed the emotional responses of social media users to a distinctive digital governance technology from 2020 to 2022. It explored how different user groups assess governmental management strategies and tools during public health crises. Moreover, it evaluated the suitability of integrating digital governance technologies into social governance processes, which is crucial for enhancing the efficacy of contemporary public emergency management.

Health Code Functions and Role in Governance

In the context of digital governance, the Health Code serves three distinct functions. First, it is a standardized authentication mechanism for the categorized management of public place entrances. The health status and validity period of the code holder are instantly apparent upon scanning, facilitating the enforcement of verifications. Second, the Health Code serves as a digital conduit connecting individuals to authentication agencies. It enables individuals to engage in health certification and assists agencies in executing social mobilization. Specific QR codes are established in public places, which individuals can scan through the Health Code to “check-in,” producing personal movement data that are subsequently integrated into the databases of authentication agencies. Finally, the Health Code is a critical component of the national certification system, and governance activities are conducted based on certification outcomes. The backend operation of the Health Code

encompasses data collection, aggregation, analysis, feedback, and visualization (Liang, 2020). These data were implemented for precise pandemic prevention measures. Lee et al. (2025) demonstrated that digital governance technologies increase administrative efficiency during emergencies and bolster governmental capacity to manage complex crises. The Health Code, an archetypal digital governance instrument, was swiftly implemented and consistently refined throughout the pandemic, exemplifying how technology can empower governance and enhance urban resilience.

From the user's perspective, the Health Code enhanced the practicality of governance technology during epidemic control, resulting in public satisfaction, as evidenced by high emotional values and positive sentiments. This corresponds with surveys regarding the public's willingness to use digital contact-tracing applications in countries like the UK and France (Altmann et al., 2020), indicating global public endorsement for digital epidemic mitigation and the readiness to adopt such software. This is connected to the reliable and time-saving advantages of digital contact-tracing initiatives (Anglemyer et al., 2020). Examining public emotional expressions at two different stages indicated that the utilization of the Health Code was influenced by the pandemic context. An increased perception of epidemic risk was correlated with a heightened frequency of Health Code utilization and functional demand. The Health Code was integrated into various management strategies to control the pandemic. Following the government's integration of essential preventative and control measures, functions such as nucleic acid testing results, vaccination status, and health conditions were incorporated into the Health Code, hence augmenting public reliance on it. Therefore, expectations regarding the user experience, encompassing the information and service quality of the Health Code, have also increased. Official media emphasized the implementation of epidemic prevention measures and the safeguarding of public life and health, thus centering discussions on the functionality promotion and usage guidance for the Health Code and addressing public inquiries. Through dialogue and interaction, both parties enhanced their understanding of the Health Code and preventive measures.

Data privacy concerns regarding digital governance technologies, such as the Health Code, are significant and similar to issues highlighted

with international digital contact-tracing programs (Legido-Quigley et al., 2020). Concerns also encompass apprehensions regarding trust in government (Barriga et al., 2020; Guillon et al., 2020). However, the findings of this study differ to some extent, as Weibo users expressed support for digital governance technology and trust in the government. Users prioritized the usefulness and functionality of the Health Code. In this situation, maintaining life and health safety supersedes concerns regarding potential hazards to user privacy during successive pandemic waves. This application of digital governance technology effectively addressed public needs and alleviated epidemic pressure, providing tangible support for government digital governance; however, phenomena like the “digital divide” and “regulatory capture” necessitate vigilance. In pursuing data efficiency goals using digital technologies, the aspiration for data justice (Taylor, 2017) remains a governance objective.

Public Group Categorization and Social Identity

Jo (2025) indicated that COVID-19 exerted enduring impacts on public psychology and behavior. This perspective elucidates the public’s varying emotional attitudes toward the Health Code at different stages. Netizens, the primary participants of social media platforms, have become an essential force propelling the evolution of event cognition. Users’ opinions on, emotions about, and attitudes toward the Health Code on Weibo are intricately linked to their personal experiences and others’ views on Weibo. The formation of group identity is an emotionally engaging process that relies on social emotions (Mercer, 2014). An analysis of the quantity of public posts and comments, alongside their sentiment scores, indicated a substantial volume of comments under public posts. A distinct positive correlation existed between the sentiment scores of public comments and posts. This reflects a significant emotional evaluation in the discussions surrounding the Health Code and can be elucidated through the intragroup categorization of social identity. On the Weibo platform, users often engage in activities concerning topics of interest, follow bloggers with similar preferences, post on topics of interest, and like and comment on content that captures their attention. Social identity denotes an individual’s recognition of belonging to a particular social group and the emotional and value implications

associated with membership (Tajfel, 1978). Therefore, individuals often attain social identity through social categorization and comparison (Tajfel, 1982). Comments on public posts suggest that people with similar goals and preferences are more likely to exhibit conformist behavior, such as endorsing the diverse functionalities incorporated into the Health Code or expressing dissatisfaction with frequent nucleic acid testing required to maintain a green code status. Social media platforms enhance users' identity awareness and offer channels for emotional expression (Kim et al., 2023). The platform's informational systems facilitate personal emotional expressions, circulation, and connections. Engagement behaviors like liking, commenting on, or sharing posts can be interpreted as motivational responses from the audience (Alhabash et al., 2018). The quality of likes reflects the audience's approval and support for the content on the platform (Swani & Labrecque, 2020). For instance, following the completion of the COVID-19 vaccination program, the introduction of aesthetic features such as golden skin frames for the Health Code was positively accepted by the public.

The public opinions presented on social media platforms often contrast with the narratives established by traditional media (Yi & Wang, 2022). The scope of topics addressed includes those traditionally framed by the media and those spontaneously generated by netizens (Mutz & Young, 2011), leading to increased issue-related content and fostering broader discussion. Studies have identified online opinion leaders through thematic content analysis alongside clustering and classification algorithms (Xing et al., 2022). Conversely, this study revealed that emotional expressions in public posts and comments regarding the Health Code exhibit greater diversity and intensity in their demands. Consequently, the themes in public posts encompass evaluations of the Health Code's functionality, concerns about pandemic policies, and grievances about the inconveniences arising from the Health Code's color changes during the pandemic. This is regardless of whether the emotions expressed are positive, neutral, or negative. A possible reason for this is that across the three years of the pandemic, the public has undergone a succession of adjustments in pandemic prevention policies, leading to a gradual acclimatization to the uncertainties introduced by the pandemic. The public has made an effort to psychologically envision a return to normalcy. Discussions over the Health Code signify an effort

by the public to forge an emotional social identity via social media platforms (Bagozzi & Dholakia, 2002). Research indicates that group identity intensifies when members experience delight within the ingroup or resentment toward the outgroup (Kessler & Hollbach, 2005). For instance, pursuing emotional support or connection through self-mockery regarding the pandemic in entertainment events or expressing outrage at the plight of vulnerable groups, such as the digital exclusion of older adults, may lead to collective emotional polarization. The expression of positive and negative emotions helps establish a group identity. With advancing Health Code governance technology, the public has benefited from the convenience of digital governance and heightened their emotional identification with the Health Code.

Official Stance and Official Identity

The study indicated that the emotional responses of official users about Health Code governance were more consistent and rational compared with those of the public. The topics in official posts and comments were more objective and neutral, aligning with earlier research findings. Chinese official media typically uphold a neutral or positive narrative when covering unexpected public events (Fu et al., 2012; Han et al., 2022; Liu & Boin, 2020; White & Fu, 2012), emphasizing factual reporting and policy interpretation (Wu et al., 2021). Therefore, an analysis of the emotional expressions in official posts and comments about the Health Code revealed that the initial phase emphasized the Health Code's governance functions. In this phase, the Health Code was positioned as a tool for COVID-19 management, and epidemic prevention policies were advocated. The second phase focused on the deployment of epidemic preventive measures and enhanced the efficiency of epidemic response through official media dissemination. The Health Code demonstrates the advantages of digital technology in social governance that traditional techniques cannot replicate. The successful operation of the Health Code depends on essential elements such as governance philosophy, organizational capacity, and technical foundation, all of which were adequately fulfilled. The government endorsed epidemic prevention philosophies, coordinated various platforms, and actively advocated for the utilization of the Health Code. The Health Code has

proven effective in offering comprehensive, continuous, universal, and widely acknowledged characteristics for joint prevention and control by the government and public entities. This is similarly evident on the Weibo platform, where public and official sentiments are predominantly favorable or neutral.

This study asserted that, with the strong advocacy of the government and the function of official media in disseminating Health Code technology and other preventive policies, the identity of official users was a crucial factor. Official identity, integrated within social media data, acted as a stimulus to enhance user engagement in debates. The public frequently commented on official posts to express their approval, questions, or suggestions concerning the Health Code and its associated preventive actions. Upon receiving an official response, the engagement cycle, characterized by likes, shares, and comments, intensifies, fostering a sense of “safety” among the engaged public (Chen et al., 2022). Additionally, official media collect data from public posts and comments, promptly understand public demands, and adjust and enhance preventive efforts. By refining information disclosure and communication strategies (Zhang et al., 2020) and expeditiously disseminating relevant information, official media facilitate the establishment of an “information cooperation” mechanism (Chen & Xu, 2023). This augments public trust and identification with the government. Driven by social media platforms and digital governance technologies, netizens’ emotional identification is activated and propagated (Stark, 2020), thereby aligning with official positions and identities. Despite potential disagreements and emotional conflicts in user comments on official posts, when the pandemic situation improved and optimization measures were enacted, these disparities and conflicts generally diminished during conversations. Consequently, the emotional evaluation of Health Code technology and the identification with official positions and identities improved.

Conclusion

This study analyzed Weibo data concerning posts and comments regarding the Health Code from 2020 to 2022 to assess users’ emotional evaluations and responses to the Health Code digital governance

technology. The analysis revealed that the emotions in posts and comments were predominantly neutral to positive, with discussions centering on changes to the Health Code's operation and adjustments to pandemic policies. The sentiment analysis and topic modeling revealed that the sentiment scores for public comments exceeded those for public posts. Moreover, a positive correlation was observed between the sentiment score coefficients of public and official posts. Official postings and comments intertwined and changed reciprocally, whereas public and official posts exhibited higher variability. Official posts and comments predominantly expressed neutral sentiments, whereas public posts and comments exhibited higher variation. Public emotional expressions demonstrated greater diversity of sentiments and topics, connecting the Health Code to daily life circumstances and the pandemic's evolution. Meanwhile, official media focused on promoting the Health Code digital governance technology and associated pandemic policies. This study examined users' emotional responses to Health Code technology on social media platforms and evaluated the effectiveness of digital governance within emergency management processes. In doing so, it broadens the research scope concerning emergency digital governance, social media platforms, and user group reactions.

However, the study had certain limitations. First, the absence of certain data labels precluded the execution of geospatial theoretical analysis of topics and emotions to investigate the responses of various groups. Second, a comparative analysis was not performed across several platforms to assess users' emotional reactions to different social media platforms. Overall, understanding the acceptance of digital governance among different groups can provide a reference for governments to enhance the implementation of digital governance technology and public services.

Notes

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The appendix containing more information on data analysis can be obtained by emailing the corresponding author.

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社交媒体用户对数字治理技术的情感评价： 以“健康码”为例

摘要：健康码是数字抗疫的重要进展，其技术维度显著提升了治理效能，而评估目标受众的感知价值同样关键。本研究以健康码为对象，抓取2020—2022年微博数据，采用Snow NLP与百度Senta进行情感分析，并结合LDA主题建模。结果显示，公众账号与官方账号发布的博文呈中性—偏正态分布，评论情感与之显著正相关；评论情感波动幅度大于博文。主题层面，大众话语普遍支持健康码制度，官方叙事则突出其应急快速部署特征。研究为阐释数字治理技术在应急管理中的意义与价值提供了实证样本。

关键词：健康码、数字治理、微博、情感表达、COVID-19

소셜 미디어 이용자에 의한 디지털 거버넌스 기술의 감정 평가: 건강 코드를 중심으로 한 사례 연구

초록: 건강 코드는 디지털 방역 노력에서 중요한 진전을 의미하며, 그 기술적 측면은 거버넌스의 효능을 향상시킨다. 대상 집단이 인식하는 가치를 평가하는 것은 필수적이다. 본 연구는 건강 코드에 초점을 맞추어 2020년부터 2022년까지의 웨이보(Weibo) 게시물을 추출하고, 감정 분석을 위해 Snow NLP와 Baidu Senta를 활용했으며, 잠재 디리클레 할당(latent Dirichlet allocation, LDA) 토픽 모델링을 적용했다. 연구 결과, 일반 계정과 공식 계정 모두 공개 게시물에서 중립에서 긍정적으로 편향된 감정을 나타냈으며, 댓글에서는 긍정적인 상관관계가 확인되었다. 댓글의 감정 분포는 게시물의 감정 분포보다 더 큰 변동성을 보였다. 감정 토픽에 관해서는, 일반 대중의 담론은 건강 코드 시스템에 대한 지지를 나타낸 반면, 공식적인 논의는 이 시스템의 신속한 긴급 배포를 강조했다. 본 연구는 비상 관리 프로세스에서 디지털 거버넌스 기술의 중요성과 가치를 명확히 하는 데 기여할 수 있는 연구 표본을 제공한다.

주제어: 건강 코드, 디지털 거버넌스, 웨이보(Weibo), 감정 표현, COVID-19

ソーシャルメディア利用者によるデジタルガバナンス技術の 感情評価：健康コードを事例として

要旨: 健康コードは、デジタルによる疫病対策の取り組みにおける重要な進歩を象徴しており、その技術的側面はガバナンスの有効性を高める。対象とする利用者にとっての認識価値を評価することは不可欠である。本研究では、健康コードに焦点を当て、2020年から2022年までのWeiboの投稿を抽出し、Snow NLPとBaidu Sentaを用いた感情分析、および潜在的ディリクレ配分(LDA)トピックモデリングを適用した。その結果、一般ユーザーと公式アカウントのいずれも、公開投稿において中立から肯定的な感情バイアスを示し、コメントでは肯定的な相関が見られた。コメントにおける感情分布は、投稿における分布よりも大きな変動性を示した。感情トピックに関して、一般の議論では健康コードシステムへの支持が示され、公式の議論ではその迅速な緊急展開が強調された。本研究は、緊急事態管理プロセスにおけるデジタルガバナンス技術の意義と価値を明確にするための研究サンプルを提供するものである。

キーワード: 健康コード、デジタルガバナンス、Weibo、感情表現、COVID-19

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