Social media in healthcare emergency management: insights from Spanish hospitals during the COVID-19

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Abstract

Purpose: This study aims to explore the Facebook communication strategies of Spanish hospitals during health emergencies, focusing on their role in crisis management and public information dissemination.

Design/methodology/approach: Automatic topic modelling and deep learning sentiment analysis were applied to analyse 151,738 posts from 274 hospital Facebook pages (March 2020-Feb 2022). Regression analyses were used to explore the relationships between topics, sentiment scores, and hospital characteristics.

Findings: The analysis revealed nine main topics, with the three most prevalent related to COVID-19: vaccine information, security measures, and situational updates. This indicates that Spanish hospitals significantly relied on Facebook to manage the emergency. The communication strategies dynamically adapted to the intensity of the pandemic and varied across hospital types. Sentiment analysis showed a negative tone for posts about security measures and situational updates. These findings align with the Agenda-Setting Theory, suggesting that hospitals influenced public discourse. Vaccine information posts were more positive, resonating with the Uses and Gratifications Theory by fulfilling the audience's need for reassurance and guidance.

Originality/value: Using replicable machine learning techniques, this study elucidates the communication strategies employed by Spanish hospitals to manage healthcare emergencies, such as the COVID-19 pandemic. It highlights factors that potentially influence these strategies and provides theoretical justifications for them. The variation in communication strategies on Facebook among different hospital categories underscores the imperative for stricter guidelines and regulations to guarantee consistent and reliable communication during emergencies. This research provides valuable insights for practitioners and policymakers aimed at developing effective health communication strategies on social media.

1 Introduction

Recent research highlights the growing utilization of social media (SoMe), particularly Facebook, by healthcare organizations in the U.S. and Western Europe (Griffis *et al.*, 2014; Martinez-Millana *et al.*, 2017). This trend aligns with the Health 2.0 movement, which advocates for interactive web technologies in healthcare (Van De Belt et al., 2012; Griffis et al., 2014). SoMe platforms facilitate the rapid distribution of health information to diverse groups, including marginalized ones, and are increasingly used by individuals seeking health information online (Boylan et al., 2020; Griffis et al., 2014; Kordzadeh and Young, 2018; Richter et al., 2014). Importantly, SoMe communication has shown potential in altering unhealthy behaviors and advancing public health (Costa-Sánchez et al., 2016; Kordzadeh and Young, 2015; Liu, 2021).

Hospitals leverage SoMe not only for public health promotion but also to enhance their marketability, with active online presence suggesting modern treatment capabilities (Bermúdez-Tamayo et al., 2013; Griffis et al., 2014). However, concerns arise over one-sided communication, potentially misleading advertising, poor-quality information, and privacy breaches (Bermúdez-Tamayo et al., 2013; Lee Ventola, 2014; Reissis et al., 2017; Sugawara et al., 2020; Yap et al., 2023). The COVID-19 pandemic further transformed this landscape, as hospitals increasingly turned to SoMe for guidance and information dissemination amidst emergency scenarios (Oosterhoff et al., 2023; Rodriquez, 2023), making their SoMe platforms critical sources of authoritative information (Cannaerts, 2021).

In this study, we sought to shed light on how the COVID-19 pandemic affected the communication of Spanish hospitals on Facebook, the most popular social network (Costa-Sánchez et al., 2016; Martinez-Millana et al., 2017). More specifically, we empirically addressed the following research questions:

RQ1: What are the main topics discussed by Spanish hospitals on their Facebook pages during the COVID-19 pandemic?

RQ2: Does the prevalence of COVID-19 topics on the Facebook pages of Spanish hospitals change according to the characteristics of the hospitals?

RQ3: Do Spanish hospitals adjust the prevalence of topics about COVID-19 on their Facebook pages according to pandemic severity?

RQ4: How does the prevalence of COVID-19 topics affect the tone of posts on Facebook pages of Spanish hospitals?

During a pandemic, it is expected that hospital communication strategies would heavily focus on COVID-19 due to the public's need for information. However, our study examines whether this expectation aligns with the actual SoMe practices of Spanish hospitals, specifically analysing the prevalence of COVID-19 topics in their Facebook posts and the dynamics of these communications during the pandemic.

To answer our research questions, we applied an automatic topic modelling procedure called latent Dirichlet allocation (LDA) (Blei et al., 2003) to a sample of 151,738 posts published on 274 hospital Facebook pages during the pandemic period from 1 March 2020 to 28 February 2022. Subsequently, we performed regression analyses to assess whether the prevalence of COVID-19 topics on Facebook changes with the characteristics of the hospitals and if the hospitals adjusted the prevalence of COVID-19 topics according to the pandemic severity. Finally, we applied a sentiment analysis procedure based on supervised deep learning (Pérez et al., 2021) to determine the tone adopted by hospitals in posts dealing with COVID-19, and how the prevalence of each COVID-19 topic affects this tone. We analysed our findings within the frameworks of the Agenda-Setting Theory (Mccombs and Shaw, 1972) and the Uses and Gratifications Theory (Katz et al., 1973).

Previous studies have examined the use of SoMe by hospitals and other healthcare institutions in different countries and contexts (Gelatti et al., 2019). However, these studies mostly aimed at assessing the magnitude and/or inferring the purposes of the use through manual content analysis procedures applied to a relatively small number of posts published over a few months (Van De Belt et al., 2012; Costa-Sánchez et al., 2016; Gelatti et al., 2019; Griffis et al., 2014; Kordzadeh and Young, 2018; Martinez-Millana et al., 2017; Richter et al., 2014; Schiavone et al., 2021; Sugawara et al., 2020; Wong et al., 2016).

In contrast, to the best of our knowledge, our research is the first to apply the automatic topic modelling procedure LDA (Blei et al., 2003) to a larger sample of posts published during an extended 24-month period coinciding with the COVID-19 pandemic. Our findings, grounded in theoretical frameworks, offer objective and replicable empirical evidence concerning the communication strategies employed by Spanish hospitals during an unprecedented pandemic. Additionally, the study elucidates factors potentially influencing these strategies.

2 Literature Review and Theoretical Frameworks

The utilization of SoMe by hospitals and other healthcare institutions across various countries and contexts has evolved significantly, with a range of strategic objectives and

observed impacts. The literature highlights a notable variation in SoMe adoption and use by healthcare institutions. For instance, in the United States, most hospitals engage with at least one SoMe platform, predominantly Facebook, to facilitate a broad range of communications, including public health education and community engagement (Griffis et al., 2014; Richter et al., 2014). Conversely, in Japan, the adoption rates are considerably lower, with only 26% of hospitals and 7.7% of clinics actively using platforms like Facebook or Twitter, often constrained by national regulations concerning medical advertising (Sugawara et al., 2020).

Furthermore, thematic analyses of SoMe content from U.S. hospitals reveal a diverse array of communication themes, predominantly health information dissemination to educate the public and employee recognition (Kordzadeh and Young, 2018; Richter et al., 2014). This indicates a strategic use of SoMe for enhancing public engagement and institutional visibility. Similarly, hospitals in Spain, despite a lower overall presence compared to the U.S., show significant engagement on platforms like Facebook, with public hospitals demonstrating more active participation, likely due to their role in public health dissemination (Martinez-Millana et al., 2017). Costa-Sánchez et al. (2016) studied the paediatric Hospital Sant Joan de Déu in Barcelona, revealing that most SoMe posts primarily provide health information and serve educational purposes. The second most common focus is the dissemination of paediatric scientific work, followed by public relations and event promotion.

The content and focus of SoMe use by hospitals also adapt during health crises, such as the COVID-19 pandemic. Hospitals across different countries leveraged SoMe to distribute timely and authoritative pandemic-related information, engage with the community, and manage public relations amidst unprecedented healthcare challenges (Oosterhoff et al., 2023; Rodriquez, 2023; Schiavone et al., 2021).

The tone of hospital communication on SoMe appears to be predominantly positive and informative and may differ significantly based on the specific topic. Specifically, Lu et al. (2017) discovered that positive emotions were often expressed in messages related to treatment procedures and medications, while negative sentiments appeared in posts concerning symptoms and complications.

The strategic shift in content focus on SoMe by healthcare institutions amid the COVID-19 crisis showcases the theoretical frameworks of Agenda-Setting and Uses and Gratifications. These frameworks highlight the crucial role of the media in shaping public perceptions and meeting individual needs. The Agenda-Setting Theory, as proposed by Mccombs and Shaw (1972), suggests that the media goes beyond reflecting reality to filtering and moulding it. In this regard, healthcare institutions may have adopted this strategy by significantly focusing on

content related to the COVID-19 outbreak. By employing tailored communication tactics, these institutions could have not only educated the public on the latest developments of the pandemic but also subtly influenced the importance of health-related behaviours and protocols among the population. This intentional focus on specific pandemic-related subjects aids in crafting a narrative that gives precedence to public health and safety, consequently guiding public discussions and behaviours towards desired outcomes.

In the same vein, the theory of Uses and Gratifications Theory, as initially proposed by Katz et al. (1973), serves as a framework through which to comprehend the intricate and varied reasons underlying audience interactions with hospital SoMe content amidst the pandemic. This theory posits that individuals actively pursue media outlets that cater to specific needs such as information, personal identity, integration, social interaction, and entertainment. Within the backdrop of a worldwide health emergency, the public's involvement with SoMe content from hospitals likely arises from an immediate requirement for timely and reliable information, reassurance, and guidance to navigate the health risks presented by the virus. This theoretical framework aids in elucidating the reasons why particular types of content, such as updates on COVID-19 vaccines or preventive measures, may witness heightened levels of engagement or appreciation, as they directly address the public's needs for security and comprehension during a tumultuous period.

Furthermore, the application of these theories in the context of SoMe usage by hospitals during the pandemic reveals a dual strategy. On one hand, hospitals may have utilized SoMe as a tool for agenda-setting, focusing public attention on critical health advisories, new scientific findings, and changes in health policies. On the other hand, they may have catered to the intrinsic needs of their audience, who turn to these platforms seeking clarity and solace amid widespread misinformation. Indeed, studies have shown that during the pandemic many people were exposed to false and harmful information, including conspiracy theories, which exacerbated public anxiety and confusion (Coninck et al., 2021; Hansson et al., 2021; Soveri et al., 2021). In this challenging environment, hospitals had to not only provide accurate information but also counteract the detrimental effects of misinformation.

The dynamic interplay between the media's role in shaping what the public thinks about (agenda-setting) and what the public looks for in the media (uses and gratifications) highlights the potent influence of SoMe as a tool in public health communication strategies. The implications of these theoretical applications are profound, suggesting that healthcare providers must carefully consider not only the content but also the function of their communications. As they navigate ongoing and future health emergencies, the strategic use of SoMe by hospitals

should aim to not only inform but also engage and reassure the public, thereby fulfilling a critical role in societal well-being and public health management.

3 Methods

3.1 Data and Sample Selection

Our initial sample consisted of 831 hospitals included in the National Catalogue of Hospitals (NHC) for the year 2020, maintained by the Spanish Ministry of Health. We found that, out of these 831 hospitals, 281 (33.8%) did not have an active institutional Facebook page. Additionally, some private hospitals belonging to the same hospital group shared a Facebook page, and other public hospitals used the Facebook page of their regional public health departments. In these cases, we included only the shared Facebook pages in our sample. Consequently, we obtained 274 active Facebook pages in May 2022 at the time of our search.

We used a Python Facebook scraper to download 151,738 Facebook posts with text published on these hospital Facebook pages from 1 March 2020 to 28 February 2022. These posts represented the documents of the corpus on which we applied the topic modelling procedure.

Notably, the period of our analysis encompasses various phases of the COVID-19 pandemic, each marked by differing levels of intensity in terms of public health measures and hospital responses. To clarify the context of our study, we have identified three main subperiods:

First Wave (March 2020 - June 2020): The onset of the pandemic in March 2020 led to widespread lockdowns and stringent public health measures. Hospitals were under extreme pressure due to the sudden surge in COVID-19 cases, which likely resulted in hospital communication strategies specifically focused on urgent updates about situational developments and security measures (Rodriquez, 2023) .

Summer 2020 - Winter 2020: Following the initial lockdowns, there was a temporary relaxation of measures during the summer of 2020, but this was quickly followed by a resurgence of cases in late 2020, often referred to as the second wave. This period saw hospitals maintaining high levels of communication, particularly regarding the rollout of new public health guidelines and updates on hospital capacities (Schiavone et al., 2021).

2021 - February 2022: The vaccine rollout in early 2021 marked a significant shift in the pandemic management strategy. Hospitals began focusing more on promoting vaccine uptake, providing detailed information about vaccination points, eligibility, and post-vaccination care,

while continuing to update the public on ongoing safety measures and situational updates as new variants emerged (Antonini et al., 2022).

3.2 Variables and Baseline Regression Models

To identify the main topics discussed by Spanish hospitals on their Facebook pages during the COVID-19 pandemic (research question RQ1), we applied the LDA topic modelling procedure (Blei et al., 2003) to a corpus of 151,738 Facebook posts from 274 hospitals. The LDA method, a form of unsupervised machine learning, was used to systematically categorize and quantify the prevalence of topics within these posts, including those related to COVID-19 (*COVID_TOPIC*).

To optimize the LDA estimation, we pre-processed the text by converting it to lowercase and removing accents, punctuation, symbols, numbers, URLs, words shorter than three characters, and common stop words. We also excluded terms appearing in fewer than 20 posts or in over 80% of them. Additionally, we identified significant bigrams occurring at least 20 times, using the *lambda* proxy method (Blaheta and Johnson, 2001) for statistical association.

Further, we assessed the sentiment of COVID-19-related Facebook posts using the *pysentimiento* Python library (Pérez et al., 2021), which applies deep learning algorithms to derive a polarity score (*TONE*) from -1 (most negative) to +1 (most positive). This sentiment analysis is crucial for understanding the emotional tone of the communications and its potential impact on public perception and behaviour.

Regarding the regression models, we computed average weekly values for all variables at the hospital Facebook page level, reducing our observations to 22,657 hospital-weeks. This data consolidation allows for the inclusion of both hospital and temporal (year-week) fixed effects, crucial for isolating the effects of our independent variables on the communication strategies during the pandemic.

To address our research question RQ2, we estimated Eq. (1), a Beta regression with a logit link. This regression model is particularly suitable for our dependent variables consisting of topic prevalence (proportion), taking values greater than 0 and less than 1:

$$COVID\_TOPIC_{it} = \beta_0 + \beta_1 PRIVATE_i + \beta_2 GENERAL_i + \beta_3 BEDS_i + \sum_k \beta_k CTRLS^k_{it} + c_i + w_t + e_{it} \quad (1)$$

where, for each hospital Facebook page i in year-week t over the study period, *COVID_TOPIC* is the prevalence of each COVID-19-related topic; *PRIVATE* is an indicator variable that equals 1 for private hospitals and 0 for public hospitals; *GENERAL* is an indicator variable that equals 1 for general hospitals and 0 for specialised hospitals; *BEDS* is the natural logarithm of the number of beds per hospital; $CTRLS^k$ is a set of k control variables; c_i indicates autonomous community fixed effects (Spain consists of 17 autonomous communities); w_t indicates hospital-invariant year-week fixed effects; and e_{it} denotes the standard error term.

To control for the severity of the pandemic in terms of pressure on the hospitals, within the control variables ($CTRLS^k$), we included the number of hospitalised patients for COVID-19 each week at the provincial level per 100,000 inhabitants (*HOSPITALISED*) (data available on https://cnecovid.isciii.es/). In addition, we included the natural logarithm of the number of posts per week on each hospital Facebook page (*N_POSTS*) and topic-prevalence variables for the other non-COVID-19 topics arising from the topic modelling.

The selection of variables was informed by both theoretical frameworks and empirical evidence that underscore their significance in influencing the communication strategies of hospitals on SoMe, even during a health emergency. Specifically, the variable *PRIVATE* indicates that ownership might influence content strategies due to differing operational goals and resource availability or constraints (Griffis et al., 2014). In this regard, Medina Aguerrebere et al. (2023) emphasize that public hospitals had to quickly adapt their strategies for transparency, leadership, and risk management during COVID-19.

General hospitals (labelled as *GENERAL*) typically post a wider variety of health-related content, including educational materials, to cater to a diverse patient base. This contrasts with specialized hospitals, which focus on specific medical fields and patient demographics (Griffis et al., 2014; Kordzadeh and Young, 2018). The number of beds, logged as *BEDS*, serves as a proxy for hospital size and potentially correlates with the capacity to produce diverse content, including information dissemination during a pandemic (Martinez-Millana et al., 2017). The variable *HOSPITALISED* reflects the direct impact of COVID-19 on hospitals' operational stress and their consequent focus on SoMe communication. Higher hospitalization rates are hypothesized to correlate with increased posts about situational updates and health advisories, aligning with crisis communication theories (Reuter and Kaufhold, 2018).

The validation of these variables' influence on SoMe communication strategies is anchored in the theoretical frameworks of Agenda-Setting and Uses and Gratifications. These frameworks suggest that the content shared by hospitals is strategically tailored to respond to both external pressures, such as pandemic severity, and internal capabilities, such as hospital

type and resources (Katz et al., 1973; Mccombs and Shaw, 1972). The regression models are specified to not only quantify the influence of these variables but also control for potential confounding factors, thereby strengthening the causal interpretations of the relationships. Other studies have employed similar variables to examine organizational behaviours and strategic communication during health crises (Bermúdez-Tamayo *et al.*, 2013; Oosterhoff *et al.*, 2023).

To address our research question RQ3, we estimated Eq. (2), a Beta regression with a logit link.

$$COVID\_TOPIC_{it} = \beta_0 + \beta_1 HOSPITALISED_{it} + \sum_k \beta_k CTRLS^k_{it} + h_i + w_t + e_{it} \quad (2)$$

where, for each hospital Facebook page i in year-week t over the study period, h_i indicates unobserved time-invariant hospital fixed effects. The other variables are as defined in Eq. (1).

To address our research question RQ4, we estimated Eq. (3), a Tobit regression model including only Facebook posts mostly related to COVID-19. We considered a Facebook post to be mostly related to COVID-19 if the total prevalence of COVID-19 topics was higher than 1/3 and the prevalence of any other topic within the post. These posts represent 38.17% of the total 151,738 posts. The Tobit model is appropriate given that the polarity score (*TONE*) dependent variable is censored between -1 and +1.

$$TONE_{it} = \beta_0 + \beta_1 COVID\_TOPIC_{it} + \sum_k \beta_k CTRLS^k_{it} + h_i + w_t + e_{it} \quad (3)$$

where, for each hospital Facebook page i in year-week t over the study period, the variables are as defined in Eq. (1) and Eq. (2).

4 Results

4.1 Topic Model Estimation and Interpretation

An important input in LDA estimation is the number of expected topics within the corpus. We applied a combination of human judgement and statistical metrics to determine this number. Specifically, we used the R package *ldatuning* to compute and plot four metrics for topics ranging from 3 to 25. The results indicated that nine might be the optimal number of topics, leading to relatively low average values of the *CaoJuan2009* and *Arun2010* metrics, which needed to be minimised, and relatively high average values of the *Deveaud2014* and *Griffiths2004* metrics, which needed to be maximised.

Hence, we first estimated the LDA model with nine topics, using Gibbs sampling, hyperparameters $\alpha = 50/T$ (T = number of topics), $\beta = 0.1$, and number of iterations = 1,000. The study's topics, identified from Facebook posts, were labelled based on the 15 most associated terms and top five posts per topic. Labels were proposed independently by the four co-authors, with disagreements resolved by majority vote, aligning with past content analyses of hospital SoMe (Kordzadeh and Young, 2015, 2018; Richter *et al.*, 2014; Wong *et al.*, 2016).

We found that LDA estimations with more than nine topics did not produce any additional and clearly distinguishable topics beyond the nine identified in the first estimation. Therefore, to address our research questions RQ1, Table 1 shows the nine topics with their assigned labels and the 15 terms most likely associated with each topic in decreasing order of probability.

(Insert Table 1 here)

We identified three topics related to COVID-19 arising from the LDA estimation. Specifically, we labelled topic 3 as 'COVID-19 vaccine information', topic 4 as 'COVID-19 security measures', and topic 6 as 'COVID-19 situational updates.'

The ten posts with the highest prevalence of the topic 'COVID-19 vaccine information' primarily addressed themes related to vaccination opportunities and accessibility (e.g., '*We have a vaccination point #COVID_19 without appointment at Hospital Malvarrosa from December 13 to 17*'), eligibility criteria for vaccines (e.g., '*Dose reminder if: You are over 60 years old and were vaccinated with Pfizer or Moderna more than 6 months ago*'), instructions for post-COVID-19 vaccination (e.g., '*If you have had COVID, you can get vaccinated from 4 weeks after being POSITIVE*'), and local vaccination points and schedules (e.g., '*Check here the vaccination points #COVID_19 without appointment for first and second doses planned for the week of January 24 to 30*').

The ten posts with the highest prevalence of the topic 'COVID-19 security measures' mostly referred to hand hygiene (e.g., '*Frequent hand washing is the most important hygiene measure*'), public health recommendations (e.g., '*If you are part of this high-risk group, strictly follow these guidelines: wear a mask, wash your hands often, respect social distance, ventilate often, avoid crowded places*'), and effective use of masks (e.g., '*The mask is mandatory but remember that for it to be safe and effective, it must be used correctly'*).

The ten posts with the highest prevalence of the topic 'COVID-19 situational updates' mostly dealt with daily case updates (e.g., '*With 8 new positives and 2 cured, Melilla stands at*

137 active COVID-19 cases'), hospitalization and ICU status (e.g., '*In the Regional Hospital, there are three people with active COVID, one of them in ICU*'), testing and diagnostics (e.g., '*The results of 144 diagnostic tests (PCR) for coronavirus were received yesterday, detecting 8 new positives and the recovery of two people*'), and updates on testing capacities and policies (e.g., '*A total of 276,042 PCR and 128,646 rapid or serological tests have been conducted in the Basque Country'*).

Finally, we collectively agreed to label the rest of the topics as 'promotion of hospital services' (topic 1), 'health advice' (topic 2), 'cancer treatment and diagnosis' (topic 5), 'recognition of staff' (topic 7), 'solidarity campaigns' (topic 8), and 'research and educational programs' (topic 9). It is not surprising that the term 'lockdown' related to COVID-19 appears under the topic 'health advice' as well. LDA topic modelling allows the same term to appear under multiple topics because it identifies patterns based on the co-occurrence of words within the text. The interpretation and labelling of topics should consider the probability and context in which words appear. For example, the term 'lockdown' could be associated with advice on staying safe at home (health advice) as well as measures to control the spread of the virus (security measures).

4.2 Descriptive Statistics of the Study Variables

Table 2 shows the descriptive statistics of the variables used to address our research questions.

(Insert Table 2 here)

Notably, the means and medians of the topic prevalence variables show similar magnitudes and relatively small variations across the nine topics. Therefore, during our study period, each of the three COVID-19-related topics had a prevalence comparable to that of other topics that had been common in hospital SoMe before the pandemic (Costa-Sánchez *et al.*, 2016; Kordzadeh and Young, 2018; Richter *et al.*, 2014; Wong *et al.*, 2016). This implies that the mean (0.319) and median (0.309) of the topic prevalence of the sum of the three COVID-19 topics approximately triples the mean and median of each of the other topics, respectively. Two-tailed *t*-test and two-tailed *Wilcoxon* test support the statistical significance (p-value < 0.01) of the differences. These results suggest that topics related to COVID-19 characterised the content of Facebook posts from Spanish hospitals during the pandemic period.

The mean of *TONE* (sentiment polarity) for all posts is 0.15, the median is 0.10, and more than 75% of the observations have positive polarity (P25 = 0.00). Hence, hospitals tended to adopt a positive communication style on their Facebook pages. However, the level of positivity is significantly lower for the subsample of posts mostly dealing with COVID-19 (mean = 0.08 and median = 0.02). The average number of weekly posts (*N_POSTS*) is 6.69, and the median is 5.00, indicating active use of Facebook by Spanish hospitals during the study period. Finally, about 62% of the hospitals are private, and about 72% are general.

Lastly, the relatively low Pearson correlation coefficients among the covariates included in our regressions, coupled with the individual variance inflation factors (VIF) of these covariates being far below the maximum cut-off of 10 (Cameron and Trivedi, 2010), suggest that collinearity is unlikely to significantly bias our estimations.

4.3 Baseline Regression Results

Table 3 shows the estimations of Eq. (1) model aimed at addressing research question RQ2.

(Insert Table 3 here)

We present two specifications for each regression. In specifications (1), we do not include control variables for other non-COVID-19 topics, while in specifications (2), we include them.

Notably, the negative and significant coefficients of *PRIVATE* in all specifications (1) suggest that the three COVID-19 topics were more prevalent on Facebook pages of public hospitals than on those of private hospitals. Public hospitals might have considered SoMe an effective tool to deal with the consequences of the pandemic that particularly affected them.

However, in specifications (2), the coefficient of *PRIVATE* is negative and significant in the *COVID-19 vaccine information* regression, while it is positive and significant in the other two regressions. This indicates that, within the COVID-19 topics and when controlling for the prevalence of the other non-COVID-19 topics, public hospitals tended to post more on the COVID-19 vaccine relative to the other COVID-19 topics than private hospitals. Indeed, in Spain, vaccination of the population was managed by regional health authorities in structures mostly related to public hospitals (Antonini *et al.*, 2022).

The sign and significance of the coefficients on *GENERAL* in specifications (1) provide evidence that general hospitals tended to post more on *COVID-19 security measures* and *situational updates* and less on *COVID-19 vaccine information* than specialised hospitals.

Indeed, general hospitals might have come under greater pressure during the pandemic relative to specialised hospitals. Additionally, based on specifications (2), general hospitals tended to prioritise *security measures* within the COVID-19 topics, while specialised hospitals focused more on *vaccine information* and *situational updates*.

Finally, the sign and significance of the coefficients on *BEDS* suggest that larger hospitals tended to post more on and prioritised COVID-19 topics dealing with *vaccine information* and *situational updates*, while smaller hospitals focused more on *security measures*.

Table 4 presents the estimations of Eq. (2) model addressing our research question RQ3.

(Insert Table 4 here)

Specifications (2) include control variables for other non-COVID-19 topics, whereas specifications (1) do not. Interestingly, the coefficients on *HOSPITALISED* are only positive and significant in *COVID-19 situational updates* regressions. This suggests that Spanish hospitals intensified their situational updates on COVID-19 when they were under pressure due to the growth of hospitalized patients from COVID-19. Therefore, hospitals appeared to use SoMe as a tool for managing emergencies by disseminating timely and relevant information.

Table 5 displays the estimations of Eq. (3) model addressing our research question RQ4.

(Insert Table 5 here)

We present the following four regression specifications: in the first three specifications, each COVID-19 topic is individually included, and in the fourth specification, all COVID-19 topics are included. The estimations show that COVID-19 topics on *security measures* and *situational updates* significantly and negatively affected the tone of hospital posts, whereas COVID-19 topic on *vaccine information* had a significant and positive effect.

5 Discussion

The study analyses 151,738 Facebook posts from 274 Spanish hospitals during COVID-19, using automatic topic modelling to identify nine main topics, three specifically related to the pandemic. We label these three as COVID-19 vaccine information, COVID-19 security measures, and COVID-19 situational updates. We determine that COVID-19 topics were the most prevalent, accounting for more than 30% of the content posted on Facebook during the

period. Given that none of the other identified topics exceeded a prevalence of 12%, it is unusual for a single health topic to represent such a significant portion of hospital communications under normal circumstances (Kordzadeh and Young, 2018).

Nonetheless, while it might seem intuitive that hospitals would focus predominantly on COVID-19-related content during the pandemic, our findings show that these topics, though prevalent, did not overwhelmingly dominate the communication efforts of Spanish hospitals, comprising only around 30% of the content. This suggests a more balanced communication approach, where hospitals continued to address a broader range of health topics, reflecting the complexity of managing both COVID-19 information and other health concerns during the crisis.

Importantly, Spanish hospitals appeared to adjust and adapt their communication on Facebook to effectively manage the COVID-19 emergency. This is further evidenced by the fact that Spanish hospitals intensified their situational updates on COVID-19 when the number of hospitalizations due to the virus increased. This insight underscores the responsive nature of hospital health communication and can therefore guide future strategies on when to intensify communication for maximum public awareness. It also offers health administrators practical advice for tailoring communication strategies and efficiently allocating resources throughout different crisis phases.

These results are consistent with the Agenda-Setting Theory (Mccombs and Shaw, 1972). By prioritizing COVID-19 related topics, Spanish hospitals played an instrumental role in setting the agenda for public discourse around the pandemic. Specifically, the prevalence of COVID-19-related topics on hospital Facebook pages indicates that hospitals emphasized the pandemic's significance in the public's consciousness, thereby influencing public awareness, attitudes, and behaviours, such as adhering to safety measures and receiving vaccination. This agenda-setting approach aligns with previous studies that underscore the proactive use of SoMe by Spanish hospitals to distribute health information and educate the public, thereby shaping public health narratives during critical times (Costa-Sánchez et al., 2016; Martinez-Millana et al., 2017).

Additionally, the paper shows that Spanish hospitals used Facebook to address the public's information needs, as suggested by the Uses and Gratifications Theory (Katz et al., 1973). In particular, the information provided by the hospitals could have offered reassurance and guidance to individuals seeking reliable sources amid the flood of misinformation circulating on various media platforms (Coninck et al., 2021; Hansson et al., 2021; Soveri et al., 2021).

Public hospitals, which experienced the consequences of the pandemic more acutely, tended to post more information about COVID-19 than private hospitals. Specifically, within COVID-19 related topics, the topic of vaccine information was more prevalent on Facebook for public hospitals. General hospitals and larger hospitals, likely facing greater pressure, tended to post more about COVID-19 situational updates than specialized hospitals and smaller hospitals, respectively. These differences in communication strategies among various types of hospitals can be viewed as a manifestation of hospitals' agenda-setting roles, with each type of hospital prioritizing certain aspects of the pandemic to guide public understanding and perceptions accordingly.

Furthermore, using a deep learning sentiment analysis procedure, we evaluated the tone of posts and found that hospitals tended to alert and sensitize the public about the effects of the pandemic by adopting a relatively negative tone in posts mostly dealing with COVID-19 security measures and situational updates. Conversely, hospitals seemed to promote the benefits of the COVID-19 vaccine to combat the virus by strategically employing a relatively positive tone in posts primarily dealing with vaccination.

On one hand, this choice of tone can be interpreted as another facet of agenda-setting. Indeed, hospitals aimed to highlight the urgency and severity of the pandemic, while simultaneously promoting the benefits of vaccination. By adopting this strategic approach, they not only shaped public perceptions of the pandemic but also possibly influenced behaviours, such as compliance with safety protocols and willingness to undergo vaccination.

On the other hand, the variation in tone can be elucidated through the lens of the Uses and Gratifications Theory, suggesting an effort to cater to different emotional needs of the audience. Specifically, the adoption of a negative tone when addressing security measures and situational updates may have served to amplify awareness and underscore the pandemic's severity. Conversely, the employment of a positive tone in disseminating vaccine-related information was presumably intended to offer reassurance and encourage vaccination.

Our study extends previous research on hospital use of SoMe for public engagement and health information dissemination, as noted in studies from the U.S. and other regions (Griffis et al., 2014; Richter et al., 2014). It uniquely captures how Spanish hospitals adapted their strategies in response to the pandemic's severity, demonstrating a dynamic aspect of SoMe use not heavily emphasized in earlier literature.

This research confirms that health information and educational content continue to dominate hospital SoMe communications, akin to previous findings (Costa-Sánchez et al., 2016; Kordzadeh and Young, 2018; Richter et al., 2014). However, it also shows a focused

intensification on specific COVID-19 related topics, such as vaccine information and safety protocols, underscoring the necessity for timely communication during health crises. Moreover, the analysis reveals that the emotional tone varies with content type, aligning with Lu et al. (2017), which highlighted how sentiment could significantly impact patient engagement and perception.

Importantly, the study innovates by applying the LDA method to a large dataset, allowing for a more precise and reliable measure of topic prevalence, including non-COVID-19 topics. This methodological advancement offers a more robust analysis than previous studies that used manual content analysis on smaller datasets (Costa-Sánchez et al., 2016; Kordzadeh and Young, 2018; Richter et al., 2014; Wong et al., 2016), enhancing our understanding of the strategic and adaptable use of SoMe by hospitals during health emergencies.

6 Conclusion

Our study highlights the crucial role of SoMe in enabling hospitals to effectively manage emergencies like the COVID-19 pandemic and to disseminate vital health information. However, to maximize the potential of SoMe in managing healthcare emergencies, adopting a two-way communication strategy on these platforms, with messages tailored to the specific needs of diverse demographic groups, is crucial. This approach not only enhances the effectiveness of the messages but also improves service quality and boosts patient engagement and satisfaction (Sanguansak et al., 2017). Additionally, implementing feedback mechanisms can provide hospitals with essential insights into the reception of their communications, allowing for real-time adjustments to improve engagement and message clarity (Hether, 2014).

Moreover, our analysis indicated that hospital communication strategies during the COVID-19 crisis varied depending on hospital characteristics, reflecting the diverse roles, capacities, and interests of different types of hospitals. For instance, private hospitals might emphasize aspects of communication that enhance their marketability, contrasting with public hospitals that typically prioritize widespread public health messaging. This variation, while expected and often aligned with the specific mandates and patient demographics of each hospital type, highlights the importance of a consistent and authoritative communication framework during health emergencies. It ensures that all public messages, regardless of the source, align with national health guidelines and contribute constructively to the public discourse. Therefore, while diversity in messaging can be appropriate and informative, a coordinated communication

strategy across healthcare institutions, particularly during a crisis, is crucial to support public understanding and adherence to health directives.

To tackle these issues, enhancing internal SoMe policies and regulations in hospitals is crucial (Torpan et al., 2023). This should aim to standardize and ensure reliable communication, especially during health crises. Communication on hospital SoMe platforms should be managed by individuals who are knowledgeable about hospital guidelines, privacy laws, and the nuances of digital communication. This approach will protect patient privacy and ensure the integrity of communications. Regular assessments of SoMe performance in relation to institutional strategic goals are vital to continuously refine communication strategies to align with broader health service objectives and meet diverse patient needs.

Our research adds significant value to the health services research and policy discourse, emphasizing digital communication's essential role in healthcare. By adopting these recommendations, hospitals and healthcare providers can improve their public health management role, especially in crises, thereby enhancing the efficiency and effectiveness of health service delivery.

Future studies could investigate how hospital communication strategies on SoMe impact patient engagement and public sentiment. This research could provide valuable insights into how hospitals can enhance their SoMe practices to foster two-way communication. Such studies might involve a detailed analysis of engagement metrics and a sentiment analysis of user comments to better understand the public’s reception of and reaction to hospital posts.

Finally, future research could compare Facebook communication with other channels, such as other SoMe platforms, hospital websites, and press releases, to provide a more nuanced understanding of the role of Facebook in hospitals' emergency management strategies.

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Table 1. Top 15 most likely terms by labelled topic

Topic number/label	Top 15 most likely terms	
	Original Spanish terms	**English translation**
1) Promotion of hospital services	hospital; pacientes; servicio; unidad; paciente; profesionales; atención; equipo; calidad; urgencias; servicios; marcha; mejorar; rehabilitación; clínica	hospital; patients; service; unit; patient; professionals; attention; equipment; quality; emergencies; services; start-up; improve; rehabilitation; clinic
2) Health advice	niños; consejos; vida; salud_mental; verano; importante; forma; #salud; confinamiento; cuidar; quieres; alimentos; deporte; ayuda; importancia	kids; tips; life; mental_health; summer; important; form; #health; lockdown; look after; you want; foods; sport; aid; importance
3) COVID-19 vaccine information	salud; años; centro; vacunación; semana; andalucía; centros; mañana; junta; familias; dosis; gobierno; área; cita; consejería	health; years; centre; vaccination; week; andalusia; centres; morning; board; families; dose; government; area; appointment; counseling
4) COVID-19 security measures	información; seguridad; medidas; recuerda; #covid19; prevención; manos; casa; cataluña; mascarilla; web; importante; puedes; generalidad; consulta	information; security; measures; remember; #covid19; prevention; hands; home; catalonia; face mask; web; important; you may; generality; query
5) Cancer treatment and diagnosis	cáncer; tratamiento; enfermedad; síntomas; especialista; cirugía; diagnostico; enfermedades; dolor; tipo; consulta; mama; tratamientos; piel; estudio	cancer; treatment; illness; symptom; specialist; surgery; diagnosis; diseases; pain; type; consultation; breast; treatments; skin; study
6) COVID-19 situational updates	covid-19; pandemia; #covid19; coronavirus; casos; personas; info; sanidad; covid; #coronavirus; uci; león; frente; situación; abril	covid-19; pandemic; #covid19; coronavirus; cases; people; info; health; covid; #coronavirus; icu; león; front; situation; april
7) Recognition of staff	gracias; profesionales; año; equipo; video; familia; personal; especial; labor; residencia; esfuerzo; familiares; momentos; navidad; apoyo	thanks; professionals; year; equipment; video; family; staff; special; work; home; effort; relatives; moments; christmas; support
8) Solidarity campaigns	personas; vida; dios; año; españa; mundo; donación; proyecto; campaña; san_juan; sangre; internacional; mundial; fundación; objetivo	people; life; god; year; spain; world; donation; project; campaign; san_juan; blood; international; world; foundation; objective
9) Research and educational programs	enfermería; programa; investigación; formación; entrevista; medicina; jefe; responsable; dra; enhorabuena; director; youtube.com; pierdas; jornada; curso	nursing; program; research; training; interview; medicine; boss; responsible; dra; congratulations; director; youtube.com; lose; working day; course

Notes: The terms for each topic are displayed in decreasing order of probability as resulting from the LDA model estimation.

Table 2. Descriptive statistics of study variables

Variables	N	Mean	Std	P25	Median	P75	Min	Max
TOPICS:								
1) Promotion of hospital services	22,657	0.115	0.029	0.096	0.108	0.126	0.050	0.386
2) Health advice	22,657	0.115	0.034	0.094	0.105	0.126	0.046	0.393
3) COVID-19 vaccine information	22,657	0.107	0.032	0.089	0.098	0.112	0.044	0.517
4) COVID-19 security measures	22,657	0.109	0.028	0.092	0.103	0.119	0.049	0.358
5) Cancer treatment and diagnosis	22,657	0.119	0.043	0.091	0.103	0.133	0.048	0.454
6) COVID-19 situational updates	22,657	0.103	0.029	0.088	0.097	0.108	0.044	0.516
7) Recognition of staff	22,657	0.111	0.031	0.091	0.103	0.122	0.046	0.389
8) Solidarity campaigns	22,657	0.109	0.029	0.092	0.102	0.117	0.046	0.388
9) Research and educational programs	22,657	0.112	0.030	0.093	0.105	0.124	0.046	0.433
Total COVID-19 topics (3 + 4 + 6)	22,657	0.319	0.053	0.283	0.309	0.345	0.156	0.650
PRIVATE	22,657	0.62	0.49	0	1	1	0	1
GENERAL	22,657	0.72	0.45	0	1	1	0	1
BEDS	22,657	219	257	60	134	259	11	1,395
BEDS (log)	22,657	4.83	1.10	4.09	4.90	5.56	2.40	7.24
HOSPITALISED	22,657	9.10	12.36	1.89	5.41	11.71	0.00	183.32
TONE	22,657	0.15	0.26	0.00	0.10	0.28	-0.99	1.00
TONE (only COVID-19 posts)	14,366	0.08	0.25	-0.02	0.02	0.14	-0.99	1.00
N_POSTS	22,657	6.69	7.48	2.00	5.00	8.00	1.00	134.00
N_POSTS (log)	22,657	1.49	0.89	0.69	1.61	2.08	0.00	4.90

Notes: The sample period spans from 1 March 2020 to 28 February 2022. N is the number of hospital-weeks in the sample. TOPICS includes the list of topics arising from the LDA estimation and their prevalence; *PRIVATE* is an indicator variable that equals 1 for private hospitals, and 0 for public hospitals; *GENERAL* is an indicator variable that equals 1 for general hospitals, and 0 for specialised hospitals; *BEDS* is the number of beds per hospital; *HOSPITALISED* is number of hospitalised patients for COVID-19 each week at the provincial level per 100,000 inhabitants; *TONE* is the sentiment polarity score of each hospital Facebook post; *N_POSTS* is the number of posts per week on each hospital Facebook page.

Table 3. Beta regressions on COVID-19 topics with hospital characteristics

	COVID-19 vaccine information		*COVID-19 security measures*		*COVID-19 situational updates*	
Variables	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
PRIVATE	-0.1706***	-0.0495***	-0.0503***	0.0495***	-0.0877***	0.0074**
	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.003)
GENERAL	-0.0166***	-0.0312***	0.0750***	0.0515***	0.0226***	-0.0074**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)
BEDS (log)	0.0365***	0.0250***	-0.0288***	-0.0337***	0.0162***	0.0099***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Other topics	No	Yes	No	Yes	No	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Aut-Community FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-week FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	22,657	22,657	22,657	22,657	22,657	22,657

Notes: *, ** and *** indicate significance levels at 10%, 5% and 1%, respectively, based on two-tailed tests. Robust standard errors are presented in parentheses. Other topics are the other non-COVID-19 topics; Other controls include *N_POSTS (log)* and *HOSPITALISED*; *Aut-Community FE* denotes autonomous community fixed effects; *Year-week FE* denotes year-week fixed effects. The remaining variables are defined in the notes of Table 2.

Table 4. Beta regressions on COVID-19 topics with hospital fixed effects

	COVID-19 vaccine information		***COVID-19 security measures***		***COVID-19 situational updates***	
Variables	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
HOSPITALISED	0.0003*	-0.0001	-0.0001	-0.0003*	0.0005***	0.0003**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N_POSTS (log)	0.0085**	0.0090***	0.0034	0.0060**	0.0177***	0.0188***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Other topics	No	Yes	No	Yes	No	Yes
Hospital FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-week FE	Yes	Yes	Yes	Yes	Yes	Yes
Number of obs.	22,657	22,657	22,657	22,657	22,657	22,657

Notes: *, ** and *** denote significance levels at 10%, 5% and 1%, respectively, based on two-tailed tests. Robust standard errors are presented in parentheses. *Other topics* are the other non-COVID-19 topics; *Hospital FE* denotes hospital fixed effects; *Year-week FE* denotes year-week fixed effects. The remaining variables are defined in the notes of Table 2.

Table 5. Tobit regressions on polarity of COVID-19 hospital posts

	TONE			
Variables	**(1)**	**(2)**	**(3)**	**(4)**
COVID-19 TOPICS:				
3) Vaccine information	1.1351***			0.3121**
	(0.087)			(0.127)
4) Security measures		-0.2412***		-0.5532***
		(0.084)		(0.118)
6) Situational updates			-1.0750***	-1.1874***
			(0.094)	(0.134)
HOSPITALISED	-0.0000	-0.0001	0.0000	-0.0000
	(0.000)	(0.000)	(0.000)	(0.000)
N_POSTS (log)	-0.0112**	-0.0118***	-0.0095**	-0.0101**
	(0.004)	(0.004)	(0.004)	(0.004)
Other topics	Yes	Yes	Yes	Yes
Hospital FE	Yes	Yes	Yes	Yes
Year-week FE	Yes	Yes	Yes	Yes
Number of obs.	14,366	14,366	14,366	14,366

Notes: *, ** and *** denote significance levels at 10%, 5% and 1%, respectively, based on two-tailed tests. Robust standard errors are presented in parentheses. The variables are defined in the notes of Table 2 and Table 4.