香 港 浸 會 大 學
HONG KONG BAPTIST UNIVERSITY

Peeling off the Digital Surface of Your Anxiety: Using Machine Learning to Analyze Residents' Anxiety amid the Surging Fifth Wave of COVID-19 in Hong Kong

By Team 03 (Yupeng Li*)

1 Background and Research Objectives

Since January 2022, Hong Kong has experienced severe challenges posed by the Omicron variant of COVID-19. The COVID-19 infection was in a dire situation in Hong Kong, with 10,000 new confirmed cases reported on average each day (Centre for Health Protection, 2022). Right before the burst of the **fifth wave of the pandemic**, Hong Kong had been expecting the border reopening with mainland China with rounds of negotiations and efforts to keep the pandemic situation under control. *The suddenly acute pandemic rapidly saturated every aspect of people's lives, crashing people's dreams of reunions with family or regular economic exchanges, causing them to feel at sea, along with the unavoidable increased level of* **stress**, **anxiety**, *and* **depression** *(Choi et al., 2020; Salari et al., 2020).*

Under the surging fifth wave of COVID-19 in Hong Kong, it is reported that citizens panic bought daily necessaries amid the possibility of a citywide lockdown to survive the uncertain pandemic situation (Hutton, 2022). Aside from worries and concern regarding subsistence, meanwhile, a growing number of residents are suffering from grief, dread, and even mental health issues under the necessary regulations for epidemic prevention, according to the mental health organizations (Yeo, 2022).

This situation urgently calls for the attention and concerted efforts of all sectors in the society since the direct consequence of being immersed in negative emotions becomes a threat to both psychological and physical health (Porcelli, 2020). What's more, if the residents hold negative and passive attitudes for long, they are likely to be indifferent to the timely suggestions from medical professionals, health organizations, and public sectors, which may cause further potential harm to their health (Lu et al., 2019). Moreover, people with a state of heightened anxiety may be more susceptible to misinformation (Freiling et al., 2021), and they end up in a more irrational and polarized environment. As a result, it is imperative to figure out what Hong Kong residents are most concerned about and their corresponding emotional responses towards the surging COVID-19 related incidents and explore the possible solutions to work out a way to tide over the difficulties together and maintain social stability.

Social media is a critical information source in terms of content consumption on risks and crisis (Westerman et al., 2014), particularly for the residents in Hong Kong who are under home quarantines and obey social distancing rules. Existing studies show that textual data on social platforms can provide useful information for epidemic diseases (*e.g.*, COVID-19, H1N1, and Ebola), through, for example, tracking rapidly evolving public sentiments (Beigi et al., 2016; Chew & Eysenbach, 2010; Nemes & Kiss, 2021), measuring public interests and concerns (Wheaton et al., 2021), estimating real-time disease activity and trends, and tracking reported disease levels (Bragazzi et al., 2020). In this regards, to combat the fifth wave of COVID-19, the research team of Dr. Yupeng Li in HKBU School of Communication and Film leverages the techniques of online social media analysis to shed light on the emotion dynamics, especially those relevant to anxiety, the issues they are most concerned about, and the potential features of online content that might trigger the anxiety. Specifically, in this research, we analyze the information on a carefully chosen social platform that is popular in Hong Kong with the following objectives:

1. **to detect the online anxiety levels and their temporal dynamics from the social platform under the fifth wave of COVID-19 in Hong Kong**

2. **to discover the issues and actors in the pandemic that the public are concerned about**

3. **to explore the characteristics of posts in the social platform that explain the anxiety level, and thus provide practical insights to mitigate anxiety**

Existing studies have investigated the community responses during the early phase of COVID-19 (Kwok et al., 2020), including the anxiety in Hong Kong (Choi et al., 2020). To our knowledge, little work has been done to study the emotional responses, in particular, the anxiety of Hong Kong residents during the fifth wave of COVID-19. Therefore, we expect to shed light on the existence, dynamics, and triggers of anxiety in Hong Kong during the fifth wave of COVID-19. In response, we utilize textual data from the social platform, Baby Kingdom[1], and we take advantage of the recent development in Natural Language Processing and Deep Learning for social media data analysis.

2 Textual Data of Online Social Platform

2.1 Data collection

We collected streaming data of posts through a database engine powered by HKBU and Datago company on Baby Kingdom, a major social platform in Hong Kong where people can share and exchange comments on the COVID-19 related issues. Using the keywords listed in Table 1, we first filtered the posts of interest since January 2022. The comments of the posts were crawled as well. Table 2 demonstrates statistics of the resulting dataset.

Table 1: Keywords for post filtering.

Keywords
'COVID','Omicron','DELTA','VIRUS','疫苗','病毒','新冠','疫情','德尔塔',
'奥密克戎','肺炎','抗疫','感染','快測','檢測','確診','症狀'
'陽性','防疫','隔離','方艙','封城','清零','抢购','口罩','物资'

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[1]https://www.baby-kingdom.com/forum.php?mod=forumdisplay&fid=1111

Table 2: Statistics of our collected dataset.

Posts	Number	Comments	Number
Posts number	34	Comments number	998
Avg. word count	57.7	Avg. word count	362
Avg. comment count	29.3	Avg. comment per day	17.5
Unique users	25	Unique users	364

2.2 Data pre-processing

Data pre-processing is considered as a vital step for training machine learning models. The messages on social platforms are usually written in an informal style; thus, to prepare for the model training of machine learning, data pre-processing is needed (D'Andrea et al., 2019; Bao et al., 2014). Basically, we clean the data by removing duplicates and redundancies such as the HTML tags, punctuations, white spaces, etc. For the step of text standardization, we leveraged the OpenCC library to convert simplified Chinese characters to Hong Kong standard traditional Chinese characters.

3 Disclosing Anxiety Using Machine Learning

To better understand the anxiety in Hong Kong amid the fifth wave of COVID-19, we employ a *fine-tuned deep learning* model to analyze emotions of the comments. Then, to understand the major concerns of the public, we categorize the issues and actors of the posts by keywords, and classify post sentiments via a *text-classification deep learning* model. Finally, we leverage *negative binomial regression* to explore the characteristics of the posts that explain the anxiety level.

3.1 Detecting anxiety in comments

COVID-19 pandemic has been under the spotlight of the whole world since 2020. Many netizens expressed their opinions on the epidemic on Baby Kingdom, Weibo, and other social media platforms, which contained a lot of emotional information. Automatic recognition of emotional information in social media texts based on *natural language processing* technology can help understand the attitude of netizens towards various events and find people's emotional fluctuations in time, so as to formulate more targeted policies and guidelines, which is of important social value.

Table 3: Examples of SMP2020-EWECT COVID-19 dataset: microblogs are classified into six categories.

Emotion	Example of Text Content[*]
Happy	# 深圳 2 名新型肺炎患者痊愈 # 看到这样的好消息新闻瞬间就觉得这次冠状病毒肺炎也没那么可怕了《赞》
Angry	吃野味和隐瞒疫情的估计是同一波人，真的要死自己去死，别拉上无辜的人。
Sad	救救武汉吧，受不了了泪奔，一群孩子穿上大人衣服学着救人
Fear	对着这个症状，没病的都害怕 [允悲][允悲]
Surprise	我特别震惊就是真的很多人上了厕所是不会洗手的。。。
Neutral	辟谣，盐水漱口没用。

[*] In this dataset, simplified Chinese characters are used.

In this study, we adopted the SMP2020-EWECT COVID-19 epidemic Weibo dataset to train a deep learning model. The corpus is generated from the dataset by filtering the COVID-19 related microblogs on Weibo since the outbreak of the COVID-19. As shown in Table 3, each microblog is labeled as one of the following six categories: *Happy*, *Surprise*, *Neutral*, *Sad*, *Fear*, and *Angry*. The ratio of training set, validation set, and test set is around 8:2:3. We trained all the microblogs in the training set and only use the predicted results of the labeled microblogs to calculate the cross-entropy loss.

To build an emotion detection model, we leveraged an effective method (BrownSweater, 2021) to fine-tune a pre-trained language model Bert (Sun et al., 2019). Carrying out super large-scale pre-training on unsupervised corpora, the fine-tuned Bert model adopts the transformer (Vaswani et al., 2017) encoder as the language model, and infers the relationship between input and output completely through the so-called attention mechanism. The architecture of the model is illustrated in Fig. 1. Evaluated on the test set, the model can achieve an accuracy of 0.772 and the macro-averaged F1 score is 0.739. While the model was trained on a simplified-Chinese dataset, preliminary experiments show that models trained on simplified-Chinese datasets can be directly used to infer Cantonese texts with only slight performance reduction.
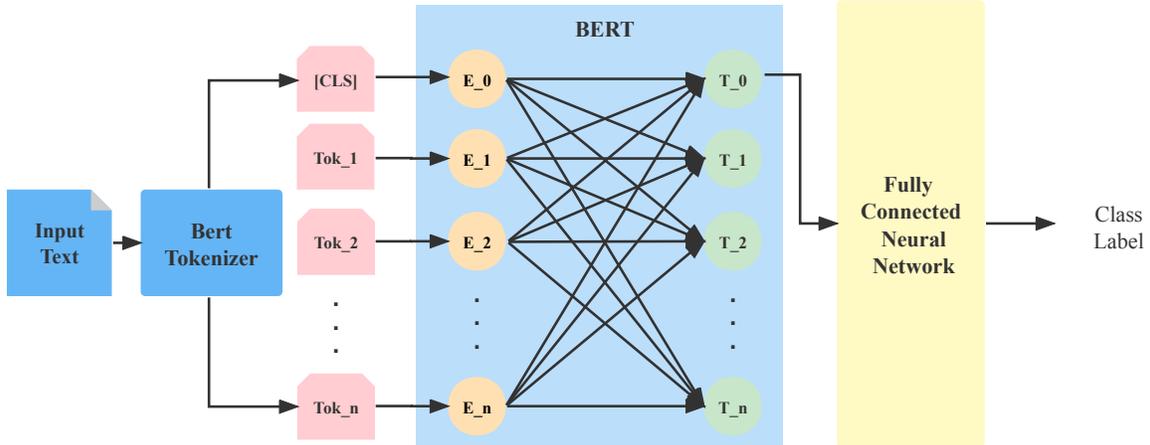
Figure 1: The architecture of our emotion detection model.

3.2 Analysing components of posts

To discover the sentiments of posts, we used another dataset[2] for sentiment analysis of Weibo users during the COVID-19 outbreak to fine-tune a Bert-based text classification model. The dataset was collected based on the keywords on 230 COVID-19 related topics. A total of 1,000,000 Weibo data were captured from Jan 1st, 2020, to Feb 20th, 2020; 100,000 of them were manually annotated into three categories: 1 (*positive*), 0 (*neutral*), and -1 (*negative*). We use a model architecture that is similar to that in Fig. 1 to infer the sentiment of our collected posts.

To further explore the post features that explain the anxiety level, we then analyze from the perspectives of issues and actors to find out the elements that Hong Kong residents pay close attention to. *The issues and actors refer to the topics of posts and the subjects that play a role in incidents, respectively.* They are identified as crucial factors that explain the degree and quality of commenting (Eisele et al., 2021). The keywords were selected through initial screening and then modified through rounds of validation. We determined the categorization for the issues and the actors based on two criteria: (1) each post is supposed to mention at least one of the identified issues; (2) the issues and the actors should be mutually exclusive, respectively. Table 4 illustrates our proposed categorization of issues and actors.

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[2]https://www.datafountain.cn/competitions/423/datasets

Table 4: Categorization for issues and actors of posts on the social platform.

Issues	Keywords
Anti-epidemic measures	防疫；抗疫；措施；禁足；隔離
Epidemic situations	疫情；第五波；通關；感染；確診
Health	打針；疫苗；口罩；中藥
Politics	政府；林太；林鄭；內地；大陸；國家
Actors	**Keywords**
HK government	政府; 港府; 立法會；林鄭；林太
Central government	中共；內地；國家；大陸
Health department	衛生署; 衛生防護中心；HKSAR；醫院管理局
Foreign government	歐美；西方

3.3 Data analysis

After categorizing issues and actors, we map these two features of the post along with the scaled sentiment and post length to each of its comments to conduct regression analysis on the comment-level data. Among all the emotions that we detected, anger, fear, and sadness are closely related to anxiety (Cattell, 1966; Carver & Harmon-Jones, 2009; Öhman, 2008; Tiller, 2013). Hence, we use the aggregate of the three emotion variables to represent the anxiety variable. Since most of the variables are dummy variables with only the level of '0' and '1', we choose the negative binomial regression to explore the characteristics that is supposed to explain the anxiety revealed in the comments.

4 Findings

To discover the *dynamics of emotions and anxiety*, we first illustrate the *temporal patterns* of emotional responses, and correlate them to the curve of new confirmed cases. Then, we compare the proportion of post components respectively to shed light on the *issues and actors* in the pandemic that the public are concerned about. Finally, through regression analysis, we discuss the effects of the post features that *explain the anxiety level*.

4.1 Dynamics of emotions and anxiety

Overall, the three anxiety-related negative emotions of *fear*, *sad* and *anger* have been fluctuating since early February, while positive emotions including *happy* and *suprise* have main-
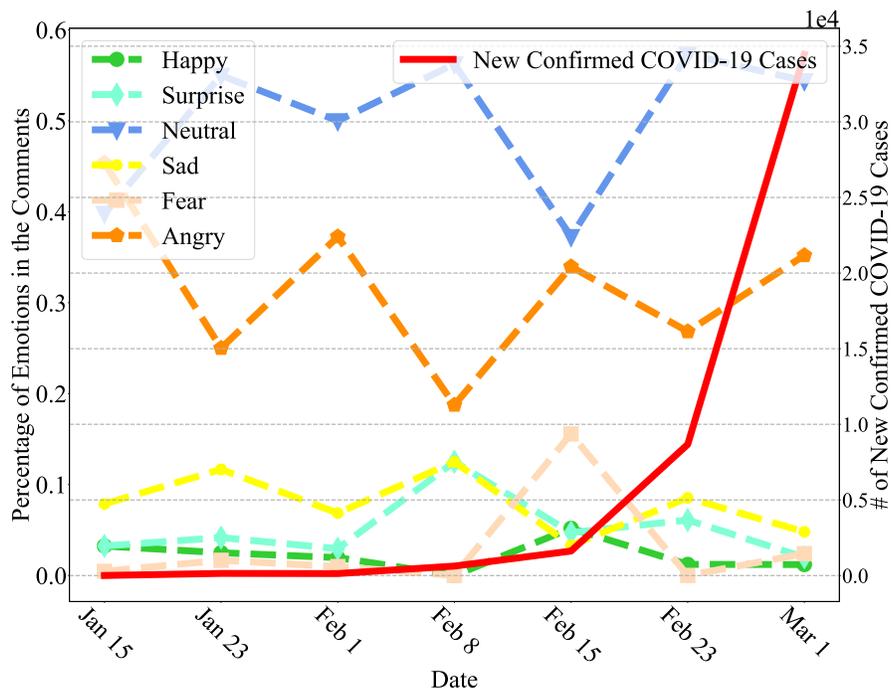
Figure 2: Emotion fluctuation and daily new case number.

tained at a low level and continued to decline since February 8th. Furthermore, we compare the patterns of dynamic fluctuation of public emotions and newly confirmed COVID-19 cases in Hong Kong.[3] As demonstrated in Figure 2, **there was a sharp increase in *fear* and *angry* in early February.** Considering that February 1st was the Lunar New Year, the cross-family gatherings, New Year's greetings, and other folk activities during the holiday made the epidemic situation worsen in early February. The number of confirmed cases increased exponentially, which rose to 1,161 on February 9th. This contextual information indicates that **in the early stage of the rapid deterioration of the epidemic, the anxiety escalated correspondingly.** While *fear* eased later, there was no downtrend in the percentage of negative comments.
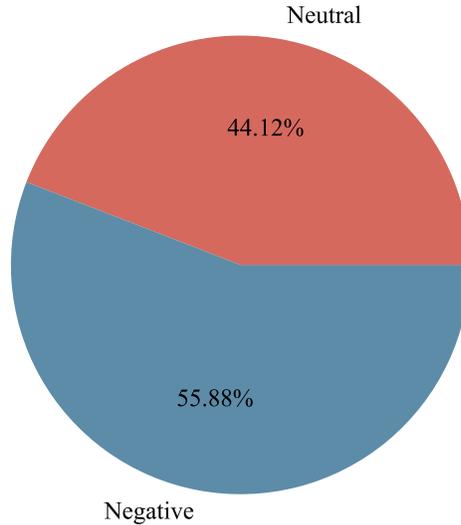
Figure 3: Distribution of sentiments in the posts: no post is identified as positive.

4.2   Components of posts

4.2.1   Sentiments

We use machine learning technique (see Section 3) to infer the sentiments of the posts. The prediction results are shown in Figure 3. According to our fine-tuned model results, more than half of the posts (56%) delivered negative messages, while 44% of collected posts used a neutral tone when discussing the COVID-19 pandemic. None of posts in our dataset were identified as positive.

4.2.2   Issues

The posts can mention more than one issues; so the total number of issues in the post reflects the aspects that Hong Kong residents are most concerned about. The most frequently mentioned issue is ***Politics*** (33%), which represents the posts that are related to opinions or discussions about the government, the political leader, and ideologies. Similar frequent issues are ***Health*** (29%), such as discussion on vaccines, masks, and traditional Chinese

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[3]COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University.
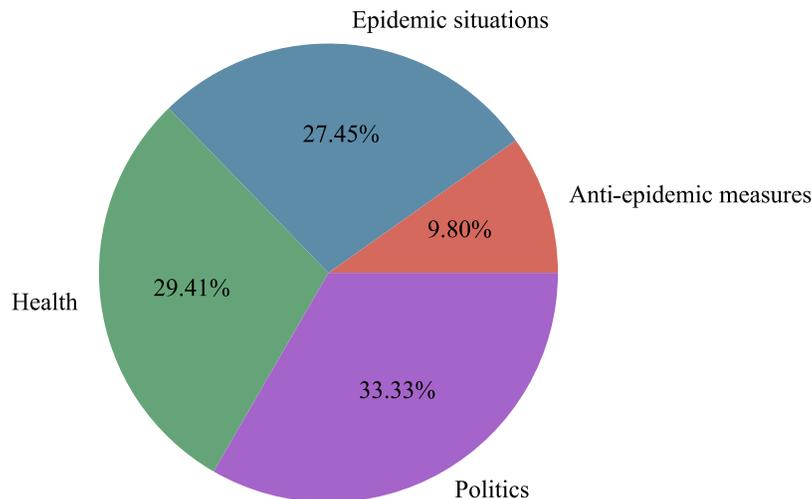
Figure 4: Distribution of issues in the posts.

medicine, and ***Epidemic situations*** (28%) , referring to the present conditions of the pandemic, such as the cases that are infected or the range of spread. It is worth mentioning that **condemnation of the irresponsible behavior or attitudes such as anti-mask and anti-vaccine accounts for a large part of *Health* issues besides worries about physical health**. People are increasingly aware that the methods with scientific evidence to prevent further spread of the virus, like wearing masks and get vaccination, are supposed to be a societal consensus (or even become a common sense) combined with collaborative efforts. The least frequent issue, according to our dataset, is *Anti-epidemic measures* (10%), which are objective statements, claims, or descriptions related to anti-epidemic measures without extended discussion. It is probably due to the common sense the simple quotes or relevant information of the pandemic prevention measures are easily available via multifarious channels and the reduplicate posts are not that necessary.

4.2.3   Actors

The actors mentioned in the posts are those that are assumed to play a role in the COVID-19 crisis. By recognizing the actors in the main body of posts in the social platform, we can figure out whom are playing (or are expected to play) a role in the rapidly evolving pandemic
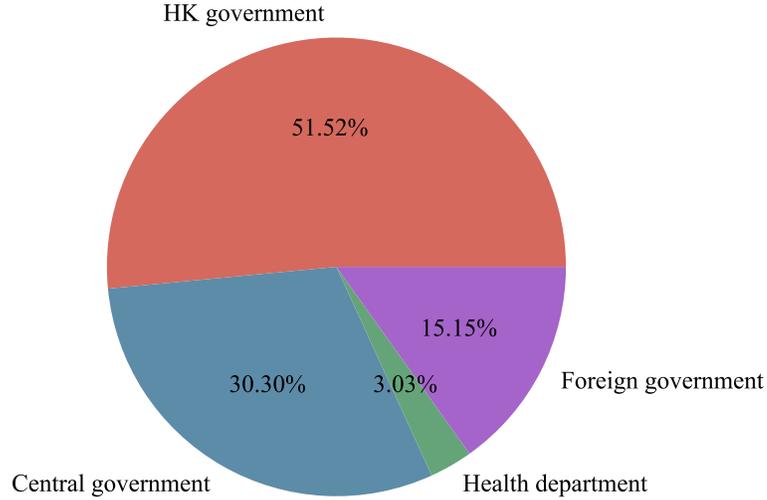
Figure 5: Distribution of actors in the posts.

situation from the Hong Kong citizens' perception. According to the categorization results, the ***Hong Kong government*** (52%) receives the most attention as anticipated. Besides, the comparison about the pandemic prevention efforts and performances is discussed in terms of different departments or governments; therefore the government of the Chinese mainland (30%) and foreign government (15%) are involved as well.

4.3   Characteristics of posts and anxiety in comments

As discussed, we analyze the regressions of the anxiety detected in comments on different combinations of the characteristics of the posts. In Table 5, we report the average marginal effects from our selected negative binomial regressions. The absolute value of the coefficient reflects the magnitude of the effect, while the sign indicates the effect direction, *i.e.*, the negative (positive) sign refers to the negative (positive) effect. Model (1) includes all the characteristics of posts, Model (2) rules out variables that have excess zeros, and Model (3) includes the variables that are commonly recognized as significant among trails of both negative binomial regressions and linear regressions.

Table 5: Negative binomial regression results.

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                                      Dependent variable:
                      -----------------------------------------------------------
                                            Anxiety
                           (1)                 (2)                 (3)
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	Anxiety (1)	Anxiety (2)	Anxiety (3)
Sentiment	−0.178 (0.114)	−0.176 (0.113)	−0.186* (0.109)
HKGovernment	0.263* (0.135)	0.255** (0.125)	0.250** (0.124)
CentralGovernment	−0.327 (0.440)		
HealthDepartment	−0.046 (0.862)		
OtherGovernment	0.151 (0.374)		
MeasurementIssue	0.171 (0.543)		
SituationIssue	−0.003 (0.133)	0.021 (0.125)	
HealthIssue	−0.414* (0.221)	−0.373* (0.197)	−0.346** (0.171)
PoliticsIssue	−0.061 (0.170)	−0.035 (0.157)	
LengthScale	−0.849 (0.568)	−0.942* (0.517)	−0.953* (0.504)
Constant	−0.827*** (0.181)	−0.847*** (0.169)	−0.875*** (0.094)

As for the actors of posts, we can observe from the table that the mention of *Hong Kong government* (corresponding to the "HKGovernment" in the table) has a positive and significant effect on the anxiety level in comments. The Omicron variant of COVID-19, in its severity, immediacy, and complexity, led government to face higher requirements raised by citizens (Hartley & Jarvis, 2020). Therefore, the anxiety may rise when the reality is inconsistent with expectations given that the epidemic is still severe. The mention of *Health* issues has a negative effect on anxiety concentration in comments. The discussions on health issues appeal for joint efforts on individual prevention, arousing few dissents.

In addition, the sentiment of posts has a negative effect on the anxiety level in comments. Since we do not identify any positive posts, our results suggest that a negative post provokes higher anxiety level than a neutral post. The emotional posts are more likely to evoke sympathy among the comments than neutral posts, since exposure to other people's

emotions online can motivate others to express similar emotions online (Goldenberg & Gross, 2020). Thus, the negative posts may be more likely to meet anxiety. The length of the post also has a negative effect on the anxiety, which means longer posts may arouse less anxiety in the comments. A more informative post helps people establish a better understanding of the current situation of the epidemic, which is associated with lower levels of anxiety (Sallam et al., 2020).

5   Insights and Future Work

Amid the fifth wave of COVID-19, there is indeed a brooding social atmosphere, in which the substantial existence of anxiety revealed in online social platforms should not be ignored. Our finding reflects that in addition to public health issues, the government needs to take the emotional problems of citizens into consideration, and provide timely guidance and assistance to mitigate anxiety for the sake of residents' psychological well-being.

The Hong Kong government is still the concern and mainstay of people's expectations for epidemic prevention. Our finding reflects that residents in Hong Kong strongly require the government to introduce more substantial and immediate measures to alleviate the intense situations, not only the pandemic itself but also problems such as supply shortage and social riots, which are the severe aftermaths of the new COVID-19 surge as well. Given the fact that the epidemic is still not optimistic, online contents that lay much emphasis on the government will drive people to put forward more urgent appeal, and anxiety will incline to rise when the reality is inconsistent with expectations.

Informative or detailed released materials may decrease the anxiety level of the audience. Our finding on the negative marginal effect of the length of content on anxiety level could offer practical implications on the organization of news coverage or government statements. The focus of the disclosure, for instance, could be on what specific problems the latest government measures or policies are about to address and what are the upcoming or validated effects, in order to fully inform citizens of the solid progress, and reduce the anxiety that arises from uncertainty.

Basic consensus on the necessity of individual epidemic protection has

been established, with further efforts needed to strengthen the cognition. From the perspective of posts on health-related issues, we find that negative sentiments are no longer out of distrust for the vaccines or mask-wearing behaviors themselves, but towards those who refuse to obey epidemic prevention regulations, posing threats to public health. Put together with the negative effect of mentioning health-related issues on anxiety, this finding indicates that the masses have reached a basic consensus, aware of the rationality of protective measures, which is an uplifting message. In order to appease the public, more efforts should not only be made to continuously promote the vaccination for targeted groups, construct the line of immune defense, and call on citizens to keep daily protection, but also to commend the value of individual epidemic prevention means in propaganda. Given the finding that less negative materials arouse less anxiety, we suggest that the disclosure of the pandemic be conveyed in a positive or at least neutral tone.

Besides the analysis conducted above, we also assume that there is supposed to be interaction terms that function in the ties between the posts and emotions of the comments. However, through our trials for both ordinary linear regressions and negative binomial regressions, the interaction terms are not significant, which might be due to our data's insufficiency for now. We plan to continuously collect the streaming data from the social platforms to dig into the interaction mechanisms and other potential predictors. In addition, the study of the detection on anxiety on social media could also be extended to other platforms, such as Facebook, to validate and enrich our findings.

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