Measuring the Outreach Efforts of Public Health Authorities and the Public Response in Facebook during the COVID-19 Outbreak in Early 2020: A Cross-Country Study with Singapore, United States of America, and United Kingdom

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Abstract

Background: The Coronavirus Disease 2019 (COVID-19) outbreak presents one of the most challenging global crisis at the dawn of a new decade. Public health authorities (PHA) are increasingly adopting the use of social media such as Facebook to rapidly communicate and disseminate outbreak response measures to the public. Understanding of communication strategies across different PHAs and the examining the publics' response on the social media landscapes can inform best practices in conveying information to the public.

Objective: This study examines COVID-19 related outreach efforts of PHAs in Singapore (SG), United States of America (US) and United Kingdom (UK) and the corresponding public response to these outreach efforts in Facebook.

Methods: Posts and comments from the Facebook pages of Ministry of Healthcare (MOH) in SG, Centers for Disease Control and Prevention (CDC) in US and Public Health England (PHE) in UK, were extracted from January 1st, 2019 to March 18th, 2020. Posts published before Jan 1st, 2020 were categorized as pre-COVID-19 while the remaining posts were categorized as peri-COVID-19 posts. COVID-19 related posts were identified and classified into themes. Metrics used for measuring outreach and engagement were frequency, mean posts per day (PPD), mean reactions per post (RPP), mean shares per post (SPP) and mean comments per post (CPP). The public response for the COVID-19 posts were measured using frequency, mean sentiment polarity (SP), positive to negative sentiments ratio (PNSR) and positive to negative emotions ratio (PNER). Toxicity in comments were identified and analyzed using frequency, mean likes per toxic comment (LPTC) and mean replies per toxic comment (RPTC). Trend analysis was performed to examine how the metrics vary with key events such as when COVID-19 was declared a pandemic.

Results: MOH publishes more COVID-19 posts (n=271, PPD=5.0) compared to CDC (n=94, PPD=2.2) and PHE (n=45, PPD=1.4). The mean number of comments per post was highest for CDC (CPP=298.3) compared to MOH (CPP=20.7) and PHE (CPP=11.5). Six major themes were identified, with posts about preventive/safety measures and situation updates being prevalent across the three countries. The themes of MOH's posts were diverse while CDC and PHE posts focused on a few themes. The number of comments spiked alongside key events. Public sentiments for MOH's COVID-19 posts were largely negative initially but improved over time. Overall, public sentiments for MOH posts (PNSR=0.9) was more favorable compared to public sentiments for CDC (PNSR=0.6) and PHE (PNSR=0.6) posts. Toxic comments were rare (0.1%) across all PHAs.

Conclusions: PHAs' extent of Facebook usage for outreach purposes during COVID-19 outbreak varied among the three PHAs, highlighting the strategies and approach other PHAs can potentially adopt. Our study showed that social media analysis is capable of assessing the effect of communication efforts by PHAs.

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Keywords: covid-19; sentiment analysis; emotion analysis; public health authorities; infectious disease outbreaks; public engagement

Introduction

Background

The Coronavirus disease 2019 (COVID-19) was first identified in Wuhan, China in the month of December 2019. It has since spread to 210 countries and territories, infecting 1,697,356 people and causing 102, 667 deaths as of April 11th 2020 [1]. Compared to the previous outbreaks Severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS), COVID-19 has caused more infections and deaths and it can be spread from an infected person to 2 to 2.5 people on average [2]. Most countries started reporting infections by the second half of January 2020. United States of America (USA) reported its first case on 20th January, 2020 [3] while United Kingdom (UK) reported its first cases on 31st January, 2020 [4]. Singapore reported its first case on 23rd January, 2020 [5]. In an effort to contain the COVID-19 outbreak in Singapore, multiple interventions have been implemented on both societal and healthcare system levels [6] and the country shifted rapidly to Disease Outbreak Response System Condition (DORSCON) Orange, the second highest level of alert for disease outbreaks in Singapore on 7th February 2020 [7], just 15 days after the first case of COVID-19 infection was confirmed. The World Health Organization (WHO) declared this disease as a pandemic on 11th March 2020, and is unable to ascertain the duration of the outbreak [8].

Countries such as Singapore, Taiwan and South Korea seem to have taken the necessary precautions to handle this outbreak within their own borders, during the month of January when the outbreak was largely confined to China [9]. On the international scene, Singapore has received accolades from World Health Organization and several world leaders praising our efforts in containing the disease [10,11]. The Dean of the Saw Swee Hock School of Public Health, National University of Singapore, has also been invited by several overseas universities to share Singapore's experience in combatting the COVID-19 outbreak [12,13]. Unfortunately, precautionary measures have been reported to be found wanting in the case of countries such as USA and UK [14,15]. It is to be noted that such delays in preparation for disease outbreaks have also been seen in the past with Zika, H1N1 and Ebola [16].

Social Media Use during Disease Outbreaks

Effective risk communication is essential in directing the public to adopt certain desired behaviors (e.g. social distancing, adopt good hygiene habits) in times of disease outbreak. Transparent and consistent communication amidst the uncertainty of the outbreak is also crucial in maintaining public confidence and trust [17,18]. Traditionally, the government and public health authorities (PHAs) relied on websites, news media, print press and the TV as main platforms for the dissemination of outbreak related news and information to the public. In contrast to the 2003 SARS and 2009 H1N1 pandemic, present day media landscapes globally have evolved significantly, with the greater presence of social media, alternative local and overseas media outlets [19]. The advent of social media platforms such as Facebook and Twitter, facilitated the instantaneous sharing of information during outbreaks in both the health authorities and the general public. With widespread social media usage and the participatory web, public health authorities (PHAs) must understand that health risk communication is no longer a linear process [20]. The public can voice their sentiment and comment on the actions undertaken by the government as events related to the outbreak unfold. The public themselves are also involved in content creation through blogs, citizen journalism and propagation information pertaining to an outbreak within their own social networks.

Existing research on social media explored outbreaks such as Zika [21–23], H1N1 [24] and Ebola [25]. The scope of these studies includes descriptive analysis of posting frequency [21], thematic analysis of post content [26], sentiments analysis of posts [23] along with social network analysis [24]. Although WHO has put forth guidelines for emergency risk communication during disease outbreaks [27], countries may adopt different strategies when conveying health risk across social media platforms. Currently, there is lack of studies that compare the social media outreach efforts of public health authorities from different countries and corresponding responses and interactions by the general public. Such studies might offer rich insights on how effectively platforms such as Facebook could be used for risk communication.

This Study

Amidst the uncertainty of a health threat such COVID-19, the public have a greater demand for real-time, transparent and consistent messaging. Government agencies run the risk of losing the centralized control of the risk communication process if they do not act swiftly to public sentiment and dispel falsehoods and misinformation [18,28]. A confluence of different factors could lead to unintended behavioral outcomes among the public in the ongoing COVID-19 outbreak. The mismatch in perceived threats as well as cost and benefit of certain health behaviors communicated by either mainstream media, government authorities or alternative media could result in distorted understanding amongst the general public. Hence, it is crucial to understand what the prevailing sentiments and narratives about the outbreak were conveyed through the different communication channels and how it was received by the general public. This will highlight the trigger points, allowing health authorities to fine-tune messaging along the course of the outbreaks to allay public fear and panic.

Hence, in this study we seek to answer four research questions related to social media usage during a pandemic. First, how frequently do the PHAs of Singapore, the United States of America (USA) and United Kingdom (UK) use the Facebook for risk communication. Second, what were the primary themes of the COVID-19 related posts by PHAs? Third, what are the public sentiments and emotions in response to these COVID-19 related posts by PHAs? Fourth, how common are toxic comments that may incite public unrest and do these toxic comments gain tractions? We have selected Singapore, USA and UK for this study as we intend to look at the findings from a cross-country perspective and these countries are developed countries with English as their official language.

Methods

Data Extraction

Data for this study were extracted from three Facebook pages using the tool Facepager [29] on 19th March 2020. The three FB pages are officially managed by Ministry of Health Singapore (MOH)[1], Centers for Disease Control and Prevention (CDC) in the United States of America[2] and Public Health England (PHE) in England[3]. Extracted data include posts by PHA, comments from Facebook users and their corresponding reactions, a feature in Facebook where users can interact with a Facebook status update, article, or a photo/video using one of six emotional reactions: Like, Love, Haha, Wow, Sad, and Angry. Contents posted between 01 Jan 2019 and 18 Mar 2020 were analyzed.

[1] Ministry of Health, Singapore https://www.facebook.com/sghealthministry. Follower count is 212,453 as of Apr 4th, 2020

[2] Centre for Communicable Disease, US https://www.facebook.com/CDC. Follower count is 2,636,072 as of Apr 4th, 2020

[3] Public Health England https://www.facebook.com/PublicHealthEngland. Follower count is 336,935 as of Apr 4th, 2020

Posts prior to 01 Jan 2020 were considered pre-COVID-19 and posts after 01 Jan 2020 were considered peri-COVID-19. We chose 01 Jan 2020 as a statement on “Precautionary Measures in Response to Severe Pneumonia Cases in Wuhan, China” was issued by the Ministry of Health (MOH) Singapore on 02 Jan 2020 [30]. COVID-19 related posts were filtered out by manually scanning through the textual content of the posts.

Data Analysis

Extent of Facebook Usage

To evaluate the extent of Facebook usage by MOH, CDC and PHE, we calculated the average number of daily posts and compared this for pre-COVID-19 and peri-COVID-19. To evaluate how specific events may influence the extent of Facebook usage, we related the number of daily posts to the key dates on which the three countries reported their first COVID-19 cases or declared the outbreak as a national level pandemic. To evaluate the extent of public engagement with the Facebook posts, we calculated the average number of reactions per post (RPP), average number of shares per post (SPP) and average number of comments per post (CPP) for pre- and peri-COVID-19 periods but focusing on COVID-19 related posts for the peri-COVID-19 period.

Thematic Analysis of COVID-19 Posts

The prevalent theme of each COVID-19 post was identified using a process involving two coders. First, the principal coder reviewed the contents of the COVID-19 posts by PHAs and assigned the relevant themes [31]. The content of the posts was first screened through and condensed into short units. The predominant theme conveyed in the post (i.e. the theme taking the larger proportion of message) will be assigned to posts with more than one theme. The list of themes included *Situation Update*, *Preventive Measures*, *Appreciation*, *Public Reassurance*, *Disease Information, Falsehood Correction*, *Face Mask, Research, Testing & Diagnosis and Miscellaneous*. Next, another coder reviewed and confirmed the themes assigned by the first coder.

Sentiment and Emotion Analyses of Comments to COVID-19 Posts

To gain insights into the reactions and comments by Facebook users on the posts by PHAs, we conducted sentiment and emotion analyses on comments written in English language. The sentiment polarity (SP) score for each comment was identified using the Vader algorithm [32] since the algorithm has been specifically conceptualized for ascertaining the sentiment in short texts (for e.g., user comments in Facebook or Tweets in Twitter). The sentiment polarity score value ranges from -1 to 1. The sentiments are classified into five categories based on the polarity scores: *Very Negative (-1<score<-0.5), Negative (-0.5<score<0), Neutral (score = 0), Positive (0<score<0.5) or Very Positive (0.5<score<1).*

For emotion analysis, we went beyond the emotions available as Facebook reactions. We adopted the eight emotions put forth in the Theory of Emotion [33] and classified the emotions of the comments as: *anger, fear, sadness, disgust, surprise, anticipation, trust,* or *joy*. Among the eight emotions, *trust* and *joy* are positive emotions while *anger*, *sadness*, *fear* and *disgust* are considered as negative emotions. *Surprise* and *anticipation* can be either positive or negative depending on the context, hence not included in either of the two categories. The emotions conveyed in the comments were identified with the help of the DeepMoji algorithm [34] using a two-step process. First, the comments were analyzed using the DeepMoji algorithm which recommends emojis based on the textual content. Second, the emotion which is mapped to the first ranked emoji, is considered as the emotion for the comment. Table A1 in Appendix lists the mapping between the emojis and the corresponding emotions.

The total number of comments, comments per post (CPP), SP scores, Positive to Negative Sentiments Ratio (PNSR) and Positive to Negative Emotions Ratio (PNER) were reported. The number of comments and the SP scores were plotted alongside the dates of key events.

Identification of Toxicity in Comments of COVID-19 Posts

Besides the general sentiment and emotion analyses, we are interested in whether there are any toxic comments that may warrant intervention. Toxicity is defined as “the usage of rude, disrespectful, or unreasonable language that will likely provoke or make another user leave a discussion” [35]. In this study, the Perspective API service of Google [36] was used to measure the toxicity of comments. The toxicity score ranges between 0 (non-toxicity) and 1 (full toxicity). We further categorized the comments into a dichotomous variable, where comments with toxicity score greater than or equal to 0.75 are toxic and comments with toxicity scores less than 0.75 are non-toxic. We examined the number of likes and replies per toxic comment to determine if such toxic comments may have any ripple effect. We compare this with number of likes and replies per non-toxic comment for reference.

Results

COVID-19 Outreach Efforts of PHAs and Public Engagement

In Table 1, the aggregated statistics related to the FB posts from MOH, CDC and PHE are listed along with the public engagement metrics. In Figure 1, the COVID-19 posts daily count values are plotted in a line graph. In addition, the key dates on which the three countries reported their first COVID-19 cases and declared the outbreak as a national level pandemic (in national terminology), are highlighted in the figure.

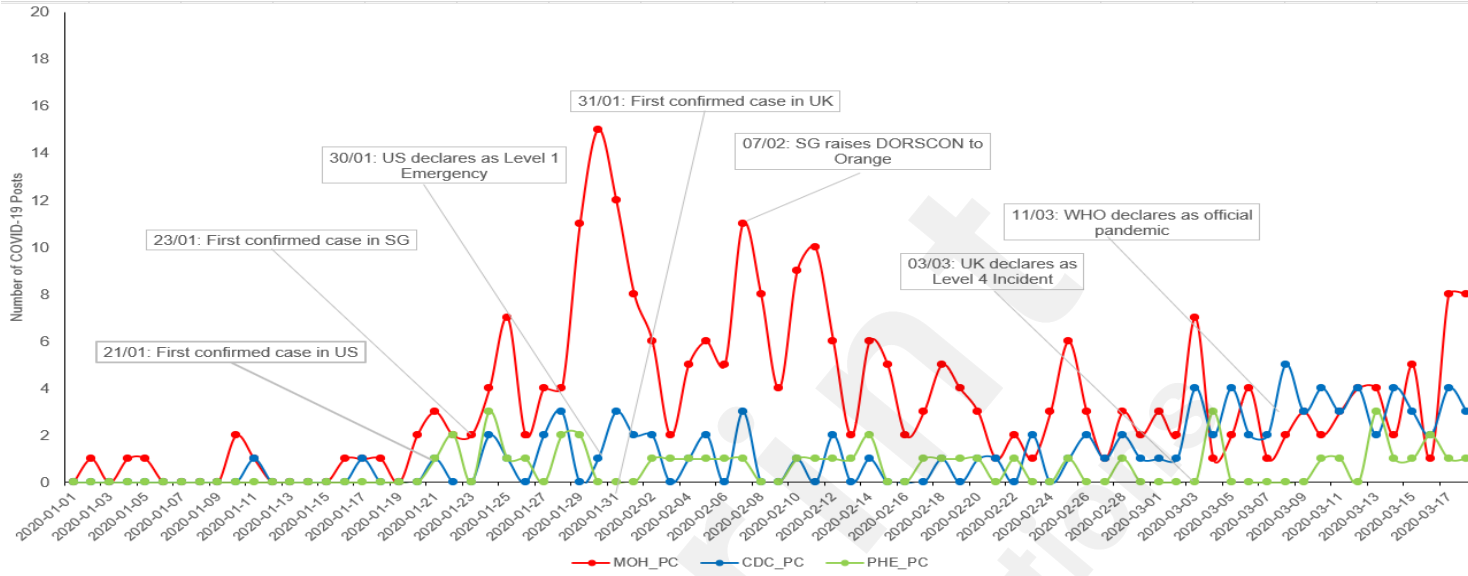
Table 1. Summary of COVID-19 Facebook outreach and engagement by MOH, CDC and PHE during the periods of pre-COVID-19 (01 Jan 2019 to 31 Dec 2019) and peri-COVID-19 (01 Jan 2020 to 18 Mar 2020).

(A)	Outreach Effort (Pre-COVID-19)		Outreach Effort (Peri-COVID-19)			
Agency	Total Posts (n)	Mean (SD) PPD	Total Posts (n)	Mean (SD) PPD	COVID-19 Posts (n, %)	Mean (SD) COVID-19 PPD Since 1st Reported Case in Each Country
MOH	192	1.4 (1.09)	304	4.3 (3.46)	271 (89.1)	5.0 (3.56)
CDC	599	2.1 (0.99)	232	2.11 (1.12)	94 (40.5)	2.2 (1.12)
PHE	346	1.3 (0.56)	87	1.6 (0.84)	45 (51.7)	1.4 (0.70)

(B)	Public Engagement (Pre-COVID-19)			Public Engagement (Peri-COVID-19)		
Agency	Mean (SD) RPP	Mean (SD) SPP	Mean (SD) CPP	Mean (SD) RPP_C19	Mean (SD) SPP_C19	Mean (SD) CPP_C19
MOH	34.3 (26.3)	20.1 (100.3)	2.2 (4.5)	188.9 (201.4)	84.6 (279.7)	15.6 (20.7)
CDC	230.7 (203.4)	240.9 (697.8)	43.1 (72.7)	2128.2 (4864.9)	2373.8 (3485.8)	255.3 (298.3)
PHE	52.4 (68.7)	102.6 (212.5)	4.3 (6.7)	101.5 (89.8)	478.9 (568.1)	12.5 (11.5)

Abbreviations: PPD-Posts Per Day, PPM-Posts Per Month,
RPP – Reactions Per Post, SPP – Shares Per Post, CPP – Comments Per Post, suffix _C19 refers to COVID19 Post

Figure 1. COVID-19 Posts Frequency During the Analysis Period



Prior to COVID-19 (01 Jan 2019 to 31 Dec 2019), CDC had an average of 2 daily posts while MOH and PPE had an average of one daily post (Table 1A). MOH stepped up on the use of Facebook for public engagement during COVID-19. As at 18 Mar 2020, MOH has already published 304 posts which is a threefold increase in their PPD from 1.35 to 4.34. During peri-COVID-19 (01 Jan 2020 to 18 Mar 2020), MOH has the highest frequency of postings among the three PHAs with 304 posts. Of these 304 posts, 271 posts (89.1%) are related to COVID-19. Mean number of daily posts was 4.3, ranging 1 to 15 daily posts. February was the most active month with 132 COVID-19 posts. Prior to the first confirmed case in Singapore on 23 Jan, there was a limited number of daily posts from MOH (ranging from 1 to 3 daily posts). However, the number of daily posts from MOH increased to 7, two days after the first confirmed case in Singapore and there have been at least 2 posts per days ever since.

CDC published 232 posts with 94 posts (40.5%) specifically for COVID-19. CDC published the highest number of COVID-19 posts in the month of March with 53 posts in the first 18 days of the month while the most number of posts published on a single day was on 8th Mar with 5 posts. CDC started to post at least one COVID-19 post every day only since 25th Feb. The number of daily posts remains low even after US has declared level 1 emergency on 30th Jan. The average number of daily posts increased only after UK declared COVID-19 as level 4 incident on 3rd Mar and rose again after WHO declares a pandemic on 11th Mar.

PHE has the lowest posting frequency (*n=87*) with only 45 COVID-19 posts (51.7%). Similar to MOH, February was the most active month with 19 COVID-19 posts for PHE while the maximum number of posts on a single day (n=3) was on 3 days - 24th January, 04th March and 13th March 2020. Despite UK declaring COVID-19 as level 4 incident on 3rd Mar, there were days when PHE has zero COVID-19 posts. PHE started posting at least one COVID-19 post every day only since 13th March.

Compared to pre-COVID-19 (Table 1B), there is also a considerable increase in the public engagement metrics in the peri-COVID-19 time period. For instance, MOH had a 7-fold increase in

comments per post, with a higher average number of people commenting in 2020 (μ=15.63) compared to 2019 (μ=2.18). CDC saw a nine-fold increase in reactions per post from 2019 (μ=230.65) to 2020 (μ=2128.2) and close to ten-fold increase in shares per post from 2019 (μ=240.93) to 2020 (μ=2373.79). In the case of PHE, the biggest rise is seen for shares per post, with nearly a 5-fold increase from 2019 (μ=102.61) to 2020 (μ=478.86).

We have also noted that Facebook users who read peri-COVID-19 posts from MOH are more likely to have a reaction to the post (average reactions per post, μ=188.91) than to share or comment on the post (shares, μ=84.6 and comments: μ=15.6) while Facebook users who read posts from CDC and PHE are more likely to share the posts (shares per post, μ=2373.79 for CDC, μ=478.86 for PHE) than to react or comment on the post. This observation was consistent in both pre- and peri-COVID-19 periods.

Thematic Analysis

The two coders decided to combine the themes *Appreciation, Research, Testing & Diagnosis* and *Miscellaneous* into a combined theme called *Others*, in order to focus on six major themes. In Table 2, we can notice that the themes from MOH are more diverse, with no theme exceeding 30% of the total posts. In contrast, the CDC and PHE posts were largely related to *Preventive Measures* (CDC: 53%. PHE: 40.0%). For MOH, *Situation Updat*e (28.8%) and *Preventive Measures* (22.1%) were the top two themes. Interestingly, CDC and PHE did not issue any post to correct false information while MOH issued 16 of such posts. There was also no post from PHE and only two posts from CDC to reassure the public while MOH issued 32 of such *Public Reassurance* posts.

Table 2. Thematic analysis of PHA COVID-19 outreach efforts

Theme	**MOH (n=271)**	**CDC (n=94)**	**PHE (n=45)**
Preventive Measures, N (%)	60 (22.1)	**50 (53.2)**	**18 (40.0)**
Situation Update, N (%)	**78 (28.8)**	21 (22.3)	7 (15.6)
Disease Information, N (%)	16 (5.9)	17 (18.1)	17 (37.8)
Public Reassurance, N (%)	32 (11.8)	2 (2.1)	0 (0)
Falsehood Correction, N (%)	16 (5.9)	0 (0)	0 (0)
Others, N (%)	69 (25.5)	4 (4.3)	3 (6.7)

Sentiment and Emotion Analyses of Comments to COVID-19 Posts

The number of comments per post was highest for CDC (n=42,470, μ=451.8), corresponding to the high number of followers for the FB page (Table 3). Although MOH has fewer number of followers than PHE, the number of comments (n=5,032) received for MOH's COVID-19 posts were five times more than PHE (n=977). This observation can also be attributed to the high number of COVID-19 posts for MOH (n=271) as against PHE's COVID-19 posts (n=45). Interestingly, the comments per post of PHE (μ=21.7) was still higher than MOH (μ=18.6). The average sentiment polarity scores of all the three PHAs were close to the neutral sentiment mark of zero with only MOH being slightly positive (μ=0.02). Correspondingly, PNSE and PNER of MOH was much higher than CDC and PHE with values of 0.84 and 0.94. However, since all these values are below 1, it is an indication there are more negative sentiments and emotions and sentiments conveyed in the comments. CDC and PHE clearly received predominantly negative comments from their followers.

Table 3. Emotion and Sentiment Analyses of COVID-19 FB Comments

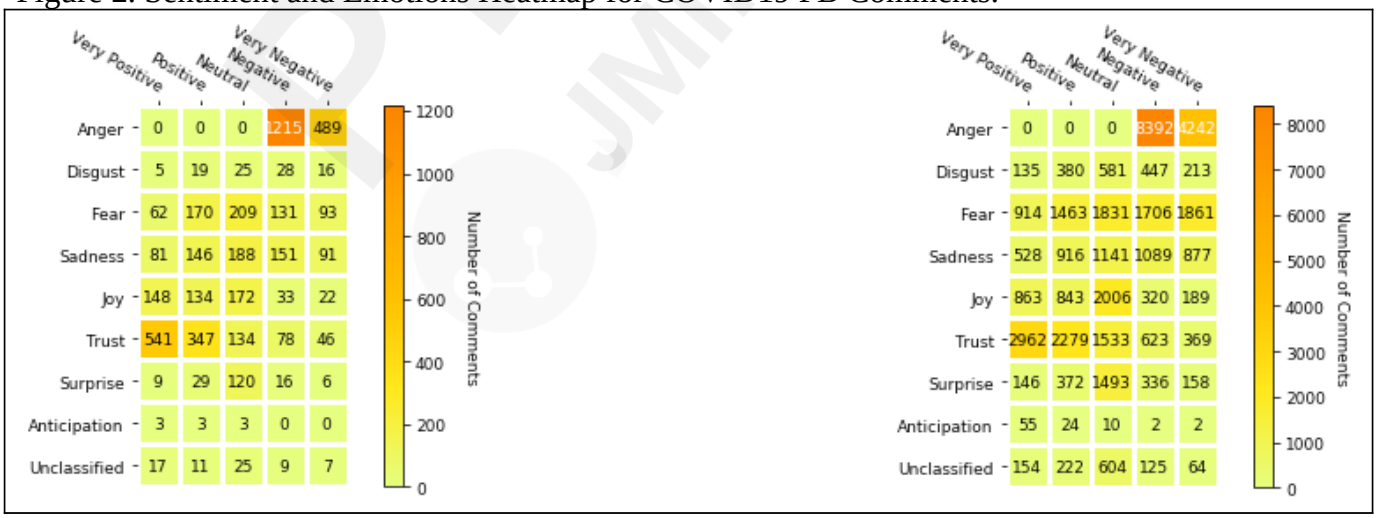
Agency	COVID-19 Posts (n)	Comments (*n*)	Mean (SD) CPP	Mean (SD) SP	Mean (SD) PNSR	Mean (SD) PNER
MOH	271	5032	18.57 (30.04)	0.02 (0.25)	0.94 (2.11)	0.84

						(1.79)
CDC	94	42470	451.81 (529.09)	-0.09 (0.06)	0.57 (0.16)	0.41 (0.12)
PHE	45	977	21.71 (31.89)	-0.14 (0.26)	0.55 (0.49)	0.44 (0.54)

Abbreviations: CPP- Comments Per Post, SP – Sentiment Polarity Score, PNSR – Positive to Negative Sentiments Ratio, PNER – Positive to Negative Emotions Ratio

In Figure 2, the emotion categories are plotted against the sentiment categories, with a darker shade of the box reflecting a higher number of comments. We observed that most comments to MOH posts were angry (1704 comments, 33.9%) with 1215 being angry and negative while 489 being angry and very negative. Anger is also the most prevalent emotion for CDC (29.8%) and PHE (30.7%). For MOH, the negative emotions (anger, disgust, fear and sadness) account for 62.0% of the comments while positive emotions (trust and joy) account for 33.0% of the comments. In the case of CDC and PHE, negative emotions accounted for 63.0% and 66.2% of comments, respectively while positive emotions accounted for 28.2% and 26.0% of comments, respectively. Since emotions have a direct effect on sentiments, the negative sentiments accounted for majority of the comments (48.3%, 49.5% and 50.3% of comments for MOH, CDC and PHE, respectively). MOH had a higher percentage of positive sentiments (34.3%) compared with CDC (28.9%) and PHE (28.4%).

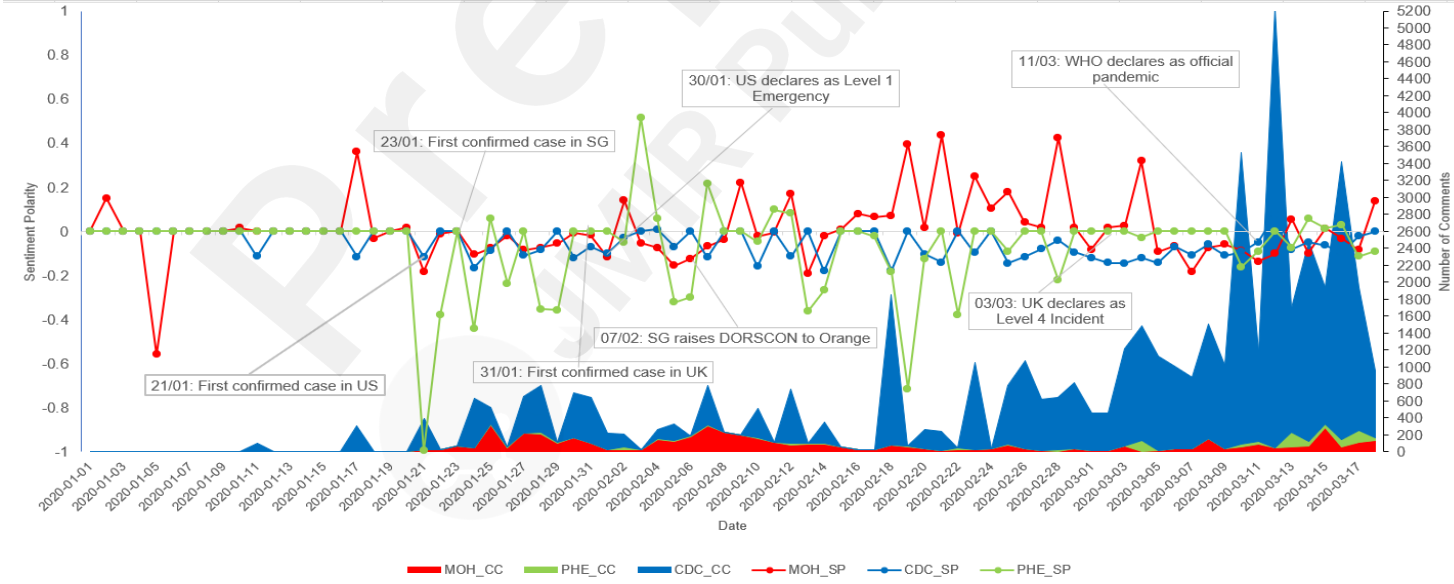
Figure 2. Sentiment and Emotions Heatmap for COVID19 FB Comments.



Left – MOH, Middle – CDC and Right – PHE

The temporal trend analysis (Figure 3) provides more information compared to the snapshots provided in Table 3 and Figure 2. For instance, we observed that the number of comments increased significantly over time for CDC posts while the number of comments for MOH posts appeared to have decreased over time. Among the three agencies, PHE has the highest degree of fluctuations in SP scores with many negative and few positive spikes. The SP scores are mostly negative for CDC posts while SP scores are positive for MOH on several occasions, which contributed to an average SP that tends towards neutral. MOH has the highest number of days with positive sentiments, particularly the period between February 16th to March 5th, which could be due to a relatively high number of appreciation posts (n=9) during that time period.

Figure 3. Temporal Trend Analysis of Number of Comments and Sentiment Polarity



Suffix Abbreviations: _CC – no. of comments, _SP – sentiment polarity scores

Identification of Toxicity in Comments of COVID-19 Posts

CDC had the highest number of toxic comments (n=728, 0.01%) followed by MOH (n=58, 0.01%) and PHE (n=12, 0.01%, Table 4). PHE had the highest average of 2.4 likes per toxic comment compared to 0.9 for CDC and 0.5 for MOH. Also, PHE's average of 2.4 likes per toxic comment is almost twice as high as the average of 1.4 likes per non-toxic comment. For CDC and MOH, the toxic comments did not receive more likes than non-toxic comments. Similarly, the average of 0.92

replies received per toxic comment was higher than average of 0.60 replies per non-toxic comments for PHE.

Table 4. Summary of COVID-19 Toxic Comments

Agency	Total no. of comments	Toxic Comments (n, %)	LPTC	LPNC	RPTC	RPNC
MOH	5032	58 (0.01%)	0.47	1.38	0.14	0.43
CDC	42470	728 (0.01%)	0.89	1.99	0.13	0.71
PHE	977	12 (0.01%)	2.42	1.44	0.92	0.60
Abbreviations: LPTC – Likes Per Toxic Comment, LPNC – Likes per Non-Toxic Comments, RPTC – Replies Per Toxic Comments, CPNC – Replies Per Non-Toxic Comments						

Discussion

Among the three agencies, MOH is the most active in using Facebook to reach out to its followers, with an average daily post of 4 that exceeded both US CDC (average daily post: 2) and UK PHE (average daily post: 1.5). MOH displayed a similar active outreach strategy during the Zika outbreak [21]. Given the large number of followers on CDC and PHE Facebook pages, it is a missed opportunity that CDC and PHE do not engage with the public more intensively using Facebook, a prominent social media platform. We observed that Facebook users who access CDC or PHE posts are more likely to share the posts rather than to react or comment on the posts. Hence, for dissemination of information, the Facebook is a useful tool for US CDC or UK PHE as they may expect their posts to be shared with other Facebook users.

The posting frequency of CDC and PHE on matters pertaining to COVID-19 was vividly low as a substantial number of post were still dedicated to other public health topics (e.g. mental health, food disease outbreak, chronic disease management). This may reflect that both countries perceived the risk of the low, or possibly that the outbreak is largely confined within Asia. During the period of our data analysis, the epicenter of the COVID-19 outbreak was Wuhan, China, with several other Asian countries, including Singapore. We observe that the volume of updates pertaining to COVID-19 related to prevention from CDC and PHE towards the end of the analysis period, which parallels the surge in case count in both the US and UK.

In our analysis of the PHA's post content, we restricted the number of themes to six as we wanted to focus on major themes unlike earlier studies where sparse set of themes were used [26]. The posts from MOH were more diverse with frequent updates on preventive measures, travel advisories, disease information, falsehood correction and even appreciation for healthcare workers and other frontliners. This is in contrast with the posts from CDC and PHE where the messages were mostly focused on preventive measures and sporadic situation updates. It is to be noted that falsehood corrections are the need of the hour as an earlier study identified that misleading Facebook posts acquired more popularity than accurate posts, during the Zika outbreak in USA [37]. On the other hand, MOH has listed misinformation debunking as one of its community and social measures as part of handling the COVID-19 situation [6]. The current distribution of themes may reflect the different phases that the three countries were going through during the period of our data analyses. We anticipate that as the disease evolves, the themes of the post will also evolve. Nevertheless, there is a need to enhance awareness for the possibility of a serious outbreak during the pre-crisis period [22]. In the case of the current COVID-19 outbreak, there is not much evidence to show for such effort from CDC and PHE.

In previous disease outbreaks, negative sentiments are generally prevalent in social media [23]. We made similar findings in our analyses where majority of the posts conveyed anger emotion and negative sentiment. In Singapore, however, we noticed that over time (from the mid of February to the first week of March), Facebook users began to be more positive about the government's response to the disease outbreak. This demonstrates that monitoring sentiments and emotions on the social media can help PHAs gauge the effectiveness of their public health education efforts. Another observation that supports the monitoring of sentiments and emotions on social media is that the number of comments tend to spike in conjunction with specific events. For example, our data showed that the number of comments sharply rose in association with the first confirmed case in US (21 Jan), when SG rose its DORSCON level to Orange (07 Feb), (3) when UK declared COVID-19 as Level 4 incident (03 Mar) and (4) when WHO declared COVID-19 as pandemic (11 Mar).

The prevalence of toxic comments for all three Facebook pages' COVID-19 posts was fairly low. It is possible that the majority of the toxic comments have been removed, and what were analyzed were those that were missed. It could also be that the toxic contents are posted on social media as independent posts rather than as comments to PHA posts. President Trump of the United States has repeatedly referred to SARS-CoV-2 as the "Chinese virus" and this has led to anti-Asian sentiments [38]. This may explain why CDC had the highest number of toxic comments. Fortunately, the number of such comments remain low and the agreement with such toxic comments is also low, as reflected by the low average number of likes per toxic comment. It will be problematic if we see a high average number of likes per toxic comment. PHAs should consider dedicating resources during a pandemic to manage toxic comments as well as combat falsehood. We observed that both CDC and PHE did not have any post to correct falsehood, unlike MOH. In contrast, social media platforms have been proactive in setting up centralized hub dedicated to COVID-19 information such as the COVID-19 Information Center on Facebook [39] or the COVID-19 Information and Resources collection on Google [40] to direct social media users to trusted and reliable sources of information.

Limitations

In this study, we have analyzed only data from Facebook. However, PHAs may use other social media platforms such as Twitter and Youtube to disseminate public health information to their citizens. Thus, this study's findings may not fully represent the overall social media outreach efforts of PHAs during the COVID-19 outbreak. In addition, the sentiments captured in FB comments may not reflect the users of other social media platforms as the profile of the users of these various platforms are known to be different. Another limitation of study is that we have limited our analyses of the public response to posts initiated by the PHAs. We have not, for instance, analyzed the comments that may have gone around within private circles. Those discussions that took place in private may be very different in nature from what are publicly disclosed. Furthermore, we have described the sentiments and emotions, but we have not analyzed the drivers of those sentiments or emotions. This will be a next step where we conduct more detailed analyses of the comments to better understand why people are feeling the way that they feel.

Conclusions

The outreach effort of PHAs in their respective social media accounts, signifies the disease management strategy enforced by the governments. Facebook provides a useful interface for public health authorities to disseminate important and crucial information to its citizens. Through our study, we were able to identify differences in the Facebook-based outreach and engagement efforts of three developed countries during the pre-outbreak and peri-outbreak periods of COVID-19. The

differences were found in terms of both publishing frequency and themes in posts. The change in public sentiments in response to specific outreach events, were also observed. On the whole, MOH stepped up its outreach efforts in Facebook while the same was not noticed for CDC and PHE. We hope that our findings will be of interest to public health authorities and health science researchers who study disease outbreaks in the context of social media. In our upcoming work, we intend to conduct studies on two related directions. In our first set of studies, we intend to collect more data from the same three PHA Facebook pages and analyze the results with data segregated in three phases (Pre-COVID-19, Peri-COVID-19 and Post-COVID-19). In the second set of studies, we intend to analyze the outreach efforts of other countries during this COVID-19 outbreak in order to understand the effectiveness and shortfalls of strategies used by different countries.

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Authors’ Contributions

WHL conceptualized the study, interpreted the data, critically revised the manuscript for important intellectual content and provided supervision.

SRA designed the study, acquired, analyzed and interpreted the data, drafted the manuscript, and critically revised the manuscript for important intellectual content.

TSG analyzed and interpreted the data, and critically revised the manuscript for important intellectual content.

All authors approved the final version of the manuscript.

Conflicts of Interest

Non declared

Abbreviations

CDC: Centers for Disease Control and Prevention (United States of America)
CPNC: Replies Per Non-Toxic Comment
CPP: Comments Per Post
DORSCON: Disease Outbreak Response System Condition
LPNC: Likes Per Non-Toxic Comment

LPTC: Likes Per Toxic Comment
MOH: Ministry of Healthcare (Singapore)
PHE: Public Health England (United Kingdom)
PNER: Positive to Negative Emotions Ratio
PPD: Posts Per Day
PSER: Positive to Negative Sentiments Ratio
RPTC: Replies Per Toxic Comment
SP: Sentiment Polarity
WHO: World Health Organization

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Appendix A

Table A1. Emojis and the associated emotions

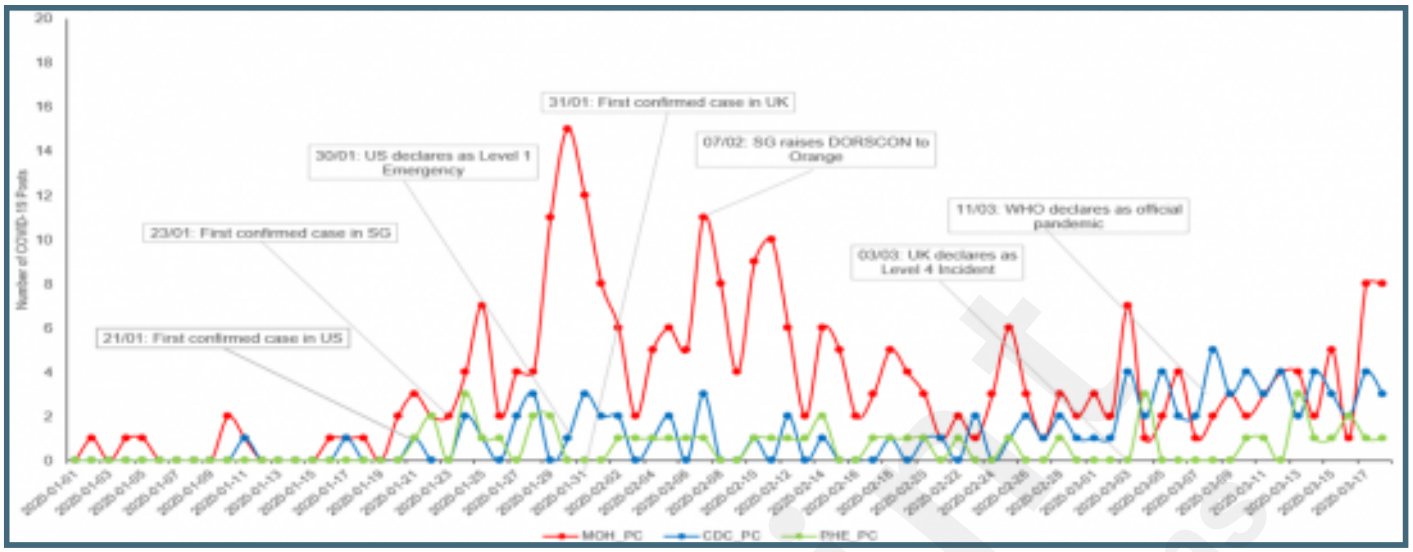
Emoji Code	Emotion
:joy:	Joy
:unamused:	Disgust
:weary:	Sadness
:sob:	Sadness
:heart_eyes:	Joy
:pensive:	Sadness
:ok_hand:	Trust
:blush:	Joy
:heart:	Anticipation
:smirk:	Joy
:grin:	Surprise
:notes:	Unclassified
:flushed:	Surprise
:100:	Trust
:sleeping:	Unclassified
:relieved:	Joy
:relaxed:	Joy
:raised_hands:	Joy
:two_hearts:	Joy
:expressionless:	Anger
:sweat_smile:	Fear
:pray:	Trust
:confused:	Sadness

:kissing_heart:	Joy
:heartbeat:	Joy
:neutral_face:	Sadness
:information_desk_person:	Disgust
:disappointed:	Sadness
:see_no_evil:	Disgust
:tired_face:	Disgust
:v:	Trust
:sunglasses:	Joy
:rage:	Anger
:thumbsup:	Trust
:cry:	Sadness
:sleepy:	Sadness
:yum:	Joy
:triumph:	Anger
:hand:	Disgust
:mask:	Fear
:clap:	Trust
:eyes:	Surprise
:gun:	Fear
:persevere:	Sadness
:smiling_imp:	Joy
:sweat:	Fear
:broken_heart:	Sadness
:yellow_heart:	Trust
:musical_note:	Unclassified
:speak_no_evil:	Fear
:wink:	Joy
:skull:	Fear
:confounded:	Sadness
:smile:	Joy
:stuck_out_tongue_winking_eye:	Joy
:angry:	Anger
:no_good:	Disgust
:muscle:	Joy
:facepunch:	Trust
:purple_heart:	Unclassified
:sparkling_heart:	Joy
:blue_heart:	Unclassified
:grimacing:	Fear
:sparkles:	Joy

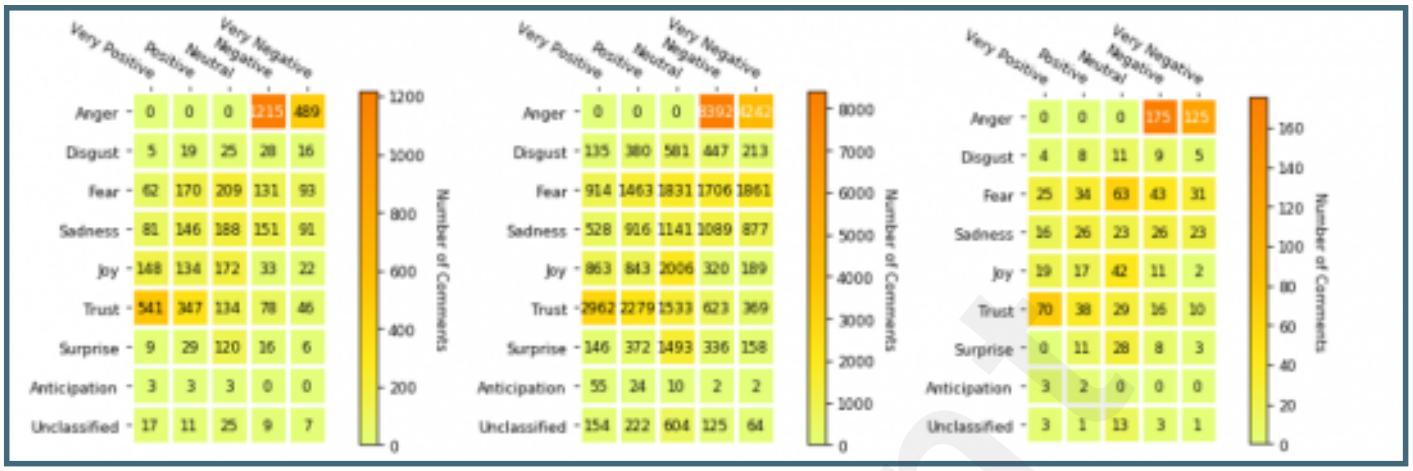
Supplementary Files

Figures

COVID-19 Posts Frequency During the Analysis Period.



Sentiment and Emotions Heatmap for COVID19 FB Comments.



Temporal Trend Analysis of Number of Comments and Sentiment Polarity.