A long-lasting public emotional trauma after the recovery of COVID-19: a full-year tracking of online public sentiment

Hao Tan, Sheng-Lan Peng, Chun-Peng Zhu, Zuo You, Ming-Chen Miao, Shu-Guang Kuai

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Abstract

Background: As the outbreak of COVID-19 has caused a wide range of panic in the general public, it is essential to understand how online public sentiments change during the pandemic given its importance for mental health policy.

Objective: Previous studies consistently showed a devastating negative impact of COVID-19 on public sentiments after the outbreak. However, it remains unclear the variation of public sentiment during the recovery phase of the pandemic.

Methods: In the current study, we continuously tracked online public sentiment through the year 2020 by analyzing emotion reflected on 64,723,242 posts across China's largest social media platform Sina Weibo.

Results: We found that the pandemic not only affected online public sentiment in the initial outbreak but also induced long-term negative effects even in the aftermath of the successful recovery from the pandemic. The long-term negative effect was not due to the pandemic's severity either locally or globally, or even the post-pandemic economic recession.

Conclusions: COVID-19 induces long-term negative effects on public sentiments even in the aftermath of the successful recovery from the pandemic. It reminds public health and government administrators of the need to pay heed to public mental health even once the pandemic has concluded.

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COVID-19 induces long-term negative effects on public sentiments even in the aftermath of the successful recovery from the pandemic. It reminds public health and government administrators of the need to pay heed to public mental health even once the pandemic has concluded.

Keywords

COVID-19, emotional trauma, online public sentiment

Introduction

The COVID-19 virus has spread rapidly throughout the world, leading to a global pandemic. As of the end of 2020, there were more than 82,386,776 infection cases and at least 1,801,092 deaths across the world [1]. To prevent the spread of the pandemic, many countries imposed different levels of restrictions in their administrations, such as locking down their cities, requiring home isolation,

banning travel, etc. COVID-19, as an infectious disease like SARS in 2003 and Ebola in 2014, has not only threatened the physical health of the public but the conditions surrounding it have imposed a wide range of negative emotions, including fear, depression, and panic disorder [2-4]. Such negative emotions could be harmful to the public's mental health and even trigger social unrest [5]. Therefore, understanding how the pandemic affects public sentiment is a means to supply valuable information for policymakers, government administrators, and mental health service providers.

After the outbreak of the pandemic, researchers conducted online or offline surveys to assess the public's mental health after the outbreak of COVID-19. These surveys consistently showed a devastating negative impact of COVID-19 on public mental health after the outbreak [6-9]. Moreover, content analysis of social media indicated a significant increase in negative emotions and a decrease in positive emotions and life satisfaction [10, 11]. Analyzing queries in search engines identified an increase in topics related to anxiety, negative thoughts, sleep disturbances, and even suicidal ideations [12, 13]. Combining the evidence of studies using different approaches, the negative impact of the outbreak on public mental health is unquestionable. However, it remains largely unknown how public sentiment varies with regard to the pandemic unfolding.

Several tracking surveys found an increase in negative emotional rating scores following the COVID-19 outbreak, such as Gopal et al. in India [14], Planchuedlo-Gomez et al. in Spain [15], Holman et al. in the USA [7], and many others. However, the literature has yielded some contrary findings. Fancourt et al. [6] and Foa et al. [12] and found negative emotional rating scores were the highest at the beginning of the outbreak and gradually decreased afterward. Zhou et al. found a slight improvement of mood after unlocking down Wuhan by comparing residents' subjective mental health before and after the city's reopening [16]. Moreover, studies using content analysis of social media and search engines showed the highest concerns and negative emotions to outbreak-related topics and there was a gradual decrease afterward, such as Lwin et al. [17], Su et al. [11], Gupta et al. [18], Saha et al. [19], Xue et al. [20], and Wang et al. [21], Yu et al. [22].
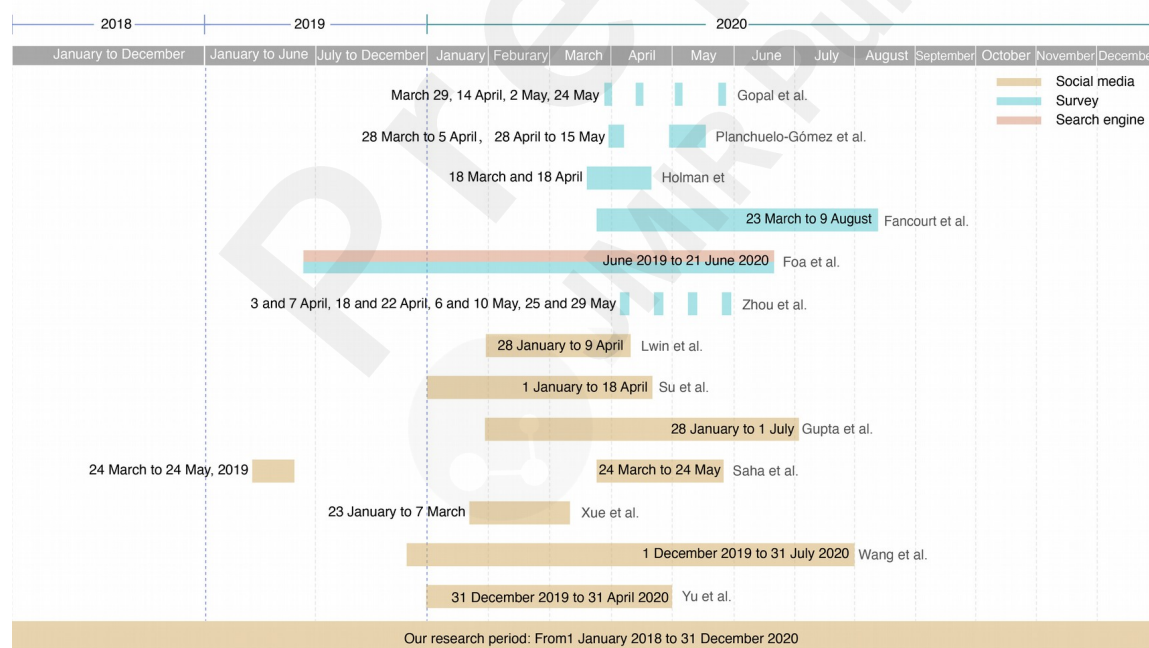

Figure 1. A literature map for studies on tracking public mental health during the pandemic. The horizontal axis labels the tracking time and different shading colors represent varying approaches to assess mental health.

Most studies have thus far focused on the psychological impact of the pandemic in the first half of the year, and neither survey nor social media sentiment analysis has assessed public sentiment

after August. The long-term effects of the pandemic on public sentiment remain largely unknown. As the China Mainland was the first region hit by the pandemic and it has been the first major economy to successfully recover from the pandemic [23, 24], monitoring online public sentiment in the China Mainland at different stages of the pandemic is a means to provide a compensative understanding of the pandemic's effect on public mental health. In this study, we tracked posts across the largest microblogging social media platform (Sina Weibo) in China [25], which is equivalent to Twitter worldwide. We analyzed the public sentiment reflected in these posts over 2020 and identified interesting short- and long-term emotional trauma that the COVID-19 response has induced.

Method
Weibo posts collections

We used a web crawler technology to collect 64,723,242 Weibo posts from 26, 895,593 accounts in 31 provinces, from 1st January 2018 to 31st December 2020 (10,072,413 posts in 2018, 21,652,707 posts in 2019, and 32,998,122 posts in 2020 years). We tried to maintain a uniform sampling across provinces to balance the regional differences, with each province getting around 3000 posts per day in 2020, 2000 posts per day in 2019, and 1000 posts per day in 2018.

We calculated the number of Weibo posts per account during our study period and found that the data followed a Zipf distribution consistent with previous research results [26]. Some accounts have published a very high number of posts, which are likely to be advertising accounts. Therefore, we retained the accounts that were within 99.99% of our distribution of the Weibo post per capita. Moreover, we filtered out the accounts verified as stars, public figures, or organizations, etc. The posts that appeared to be advertisements for marketing purposes were excluded as well. Additionally, we filtered out the posts that did not contain Chinese characters and those that exceeded 140 characters. The study was approved by the ethics committee of the authors' universities.

Sentiment value calculation
We applied the Tencent natural language processing (NLP) platform [27], a professional Chinese sentiment analysis application programming interface (API), to analyze online public sentiment [28]. The algorithm excluded numbers, punctuations, English characters, URL, hashtags, mentions, and emoji and then extracted Chinese characters, numbers, and punctuation for sentiment analysis. The algorithm generated a sentiment value score ranging from 0 (extremely negative mood) to 1.0 (strongly positive mood). We averaged mean sentiment values for all 31 provinces on the China Mainland.

Data of reported cases of COVID-19
This project obtained the data of reported cases of COVID-19 in the China Mainland from the National Health Commission of the People's Republic of China and the health commission of municipal provinces [29]. It collected data regarding global cases of COVID-19 from the World Health Organization (WHO) and Johns Hopkins Coronavirus Resource Center [1, 30].

Data of economic indicators
This project obtained data of economic indicators from the National Bureau of Statistics [31], including the consumer price index, the unemployment rate in urban areas of the China Mainland, the producer price index, and the growth rate of gross domestic product (GDP). The first three indicators were calculated per month and the GDP growth rate was calculated per quarter.

Results

Online public sentiment values across 2020 and the previous two years.

In Week 3 (January 20), human-to-human transmission of the virus was verified and announced to the public and the city of Wuhan was locked down on January 23 [32], attracting considerable public attention. As a consequence, online public sentiment values rapidly decreased, hitting their lowest in Week 5 (Figure 2a). The lowest sentiment value was reduced by more than 3.7% compared with the beginning of the year (Week 1). The sentiment values bottomed out from Week 6 and reached the peak at Week 17 (Figure 2a). After that, sentiment values surprisingly entered a long-term downward spiral until the end of the year, though the pandemic was well under control in the China Mainland. The lowest sentiment value (mean 0.496, SE 0.002) in the second half of the year was even lesser than that in Week 5 (mean 0.499, SE 0.003), marking the lowest point after the outbreak of COVID-19 in Stage 2 (Figure 2a).

It is unclear whether the decline of sentiment values in the second half of 2020 presents a long-term effect of the pandemic or if they are merely seasonal fluctuations. To answer this question, we analyzed online public sentiment values in 2018 and 2019. The sentiment values in the previous two years did not demonstrate a downward trend in the second half of the year, indicating that the downward trend is probably not a result of common seasonal fluctuations (Figure 2a). It is worth noting that we observed three peaks of online public sentiment values in Week 1, Week 7, and Week 40, which were around the New Year, Spring Festival (Chinese new year), and National Day, respectively, indicating the holiday effects of online public sentiment. The peak around the Spring Festival (Chinese New Year) period observed in the previous two years did not occur in 2020. As the Chinese New Year occurred just after the COVID-19 outbreak, one might suspect that the negative effects of the pandemic were diluted by the holiday effects of the Chinese New Year. To obtain a more accurate reading of the effect of the pandemic upon online public sentiment, it is necessary to exclude these holiday effects. We therefore estimated the holiday effects using the data of the previous two years. In particular, we computed the difference between sentiment values in the holiday week and those in the week before and after each holiday. The sentiment values in 2020 then subtracted the holiday effects for further analysis (Figure 2b).

According to the white paper published by the State Council Information Office of the People's Republic of China, Fighting COVID-19 China in Action[24], China divided its fight against the pandemic into five stages. The variations of sentiment values in 2020 were well aligned with the five stages of outbreak prevention. In Stage 1 (Week 0-3: Swift Response to the Public Health Emergency), the sentiment values had been relatively stable given the pandemic had not yet triggered nationwide attention. In Stage 2 (Week 3 - Week 8: Initial Progress in Containing the Virus), due to public concern about the pandemic outbreak, the sentiment values rapidly declined and then rebounded quickly as the government brought the pandemic under control. In Stage 3 (Week 8-Week 11: Newly Confirmed Domestic Cases on the Chinese Mainland Decline to Single Digits), sentiment values were restored to a stable level as the number of infections gradually decreased to single digits. In Stage 4 (Week 12-Week 17: Wuhan and Hubei – An Initial Victory in a Critical Battle), sentiment values once again increased and even exceeded the sentiment values in the same period in previous years. The sentiment values in Stages 2-4 correlated significantly with the number of newly confirmed cases (r=-.58, P=.03) (Figure 2b), indicating a strong correlation between online public sentiment and the pandemic's severity.

However, in Stage 5 (Week 18-Now: Ongoing Prevention and Control), there was another unexpected decline in online public sentiment values even though the pandemic was well under control at the time. Interestingly, public sentiment values in the stage were no longer correlated with the number of newly confirmed cases (r=.12, P=.50).

Figure 2. Online public sentiment values of Weibo over the last three years. (a) Online public sentiment values were plotted as a function of the week across the whole year. 2020: the solid line; averaged values of the previous two years: the dashed line. (b) Sentiment values in 2020 which exclude the holiday effects and number of newly confirmed cases per week for 2020.

Relationship between the decline of sentiment values in Stages 2 and 5

This study considers the underlying reasons for the decline in online public sentiment in Stage 5. We hypothesized that the decline of sentiment values could be an after-effect of the decline of public sentiment in Stage 2. Considering the different depths of the pandemic's severity across China, the extent of the decline in public sentiment values similarly varied across different provinces and municipalities. We reasoned that if there was a correlation between the extent of the decline of public sentiment values in Stages 2 and 5, noting that it is likely that the decline in Stage 5 reflects a long-term effect of the measures put in place to combat COVID-19. To test the hypothesis, we calculated the difference of sentiment values between Week 3 and 5 as the extent of the decline in Stage 2, while we calculated the difference of sentiment values between Week 17 and 46 as the extent of the decline in Stage 5. We observed a significant positive correlation between the extent of the decline in Stage 2 and that in Stage 5 ($r= .71$, $P<.001$), which supports our hypothesis that the decline of public sentiment values in Stage 5 reflects the long-term emotional consequences induced by the initial outbreak of the COVID-19 (Figure 3).
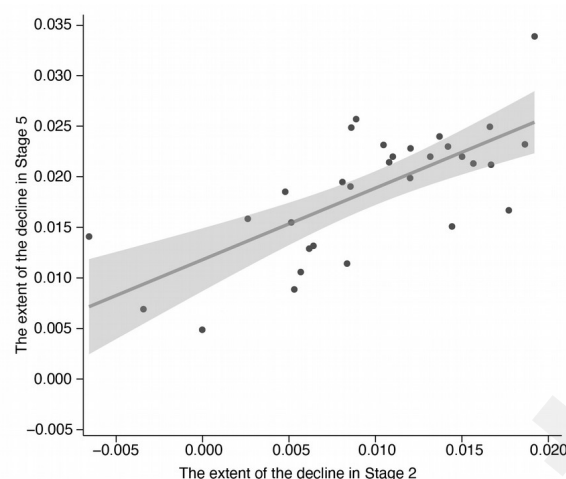
Figure 3. A correlation between the decline in online public sentiment values in Stage 2 with that in Stage 5. Black dots represent the extent of the decline of public sentiment values in each province in the China Mainland. The solid line represents a fitted linear curve of the extent of the decline in two stages (R^2=.50, *P*<.001, 95% CI 0.473–0.978).

The alternative causes inducing the decline of online public sentiment in Stage 5

Concerns about upgrading risk assessment level
In Stage 5, there remained sporadic indigenous cases. In response to the emergence of these local cases, governments upgraded the risk assessment level from low to high in Jilin (Week 19-23), Beijing (Week 24-28), Xinjiang (Week 29-35), Liaoning (Week 30-33), Xinjiang (Week 43-47), Tianjin (Week 47-49), and Inner Mongolia (Week 49-50). Upgrading the risk assessment level may have induced negative emotions in the general public. To assess whether that was indeed the case, we defined average public sentiment values in one week before and after the high-risk period as the baseline. We defined the rate of change by the difference between the average public sentiment values in the high-risk period and the baseline, then divided by the baseline. The rate of change was close to 0 either at the nationwide scale (Figure 4a, Jilin: -0.19%, Beijing: 0.18%, Xinjiang: 0.94%, Liaoning: 0.61%, Xinjiang: -0.18%, Tianjin: 0.28%, Inner Mongolia: -0.21%) or local scales (Figure 4b, Jilin: -0.13%, Beijing: -0.44%, Xinjiang: 0.17%, Liaoning: 0.57%, Xinjiang: 0.20%, Tianjin: 0.21%, Inner Mongolia: 0.05%).
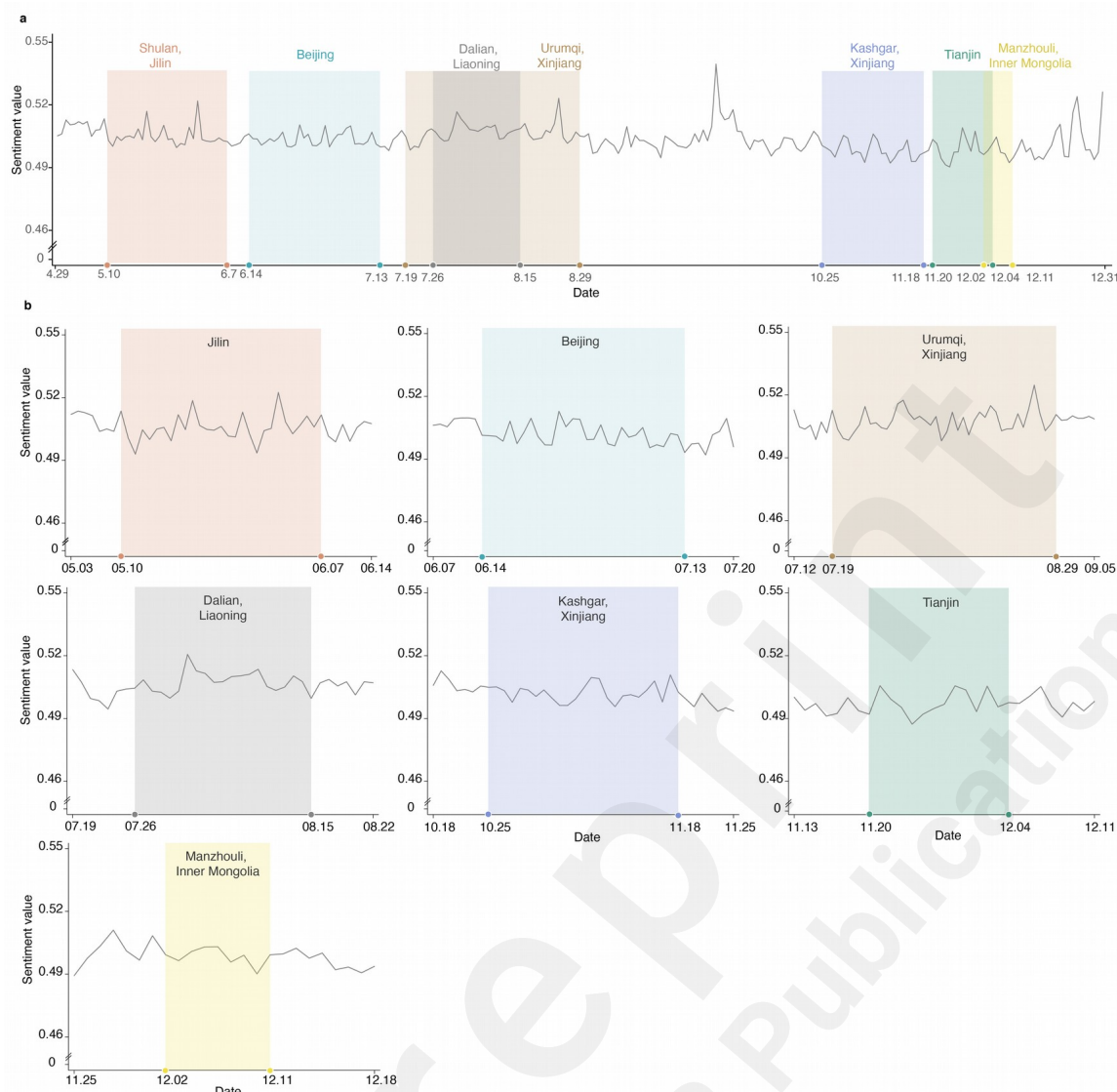
Figure 4. The effect of sporadic indigenous inflection cases in Stage 5. (a) national sentiment values in Stage 5. The time windows were labeled with underlay colors when the risk assessment level was upgraded to high risk in some areas. (b) local sentiment values in the provinces when the local risk assessment levels were upgraded.

Concerns about the economic consequences of the COVID-19 pandemic

In Stage 5, although the number of newly confirmed COVID-19 cases was relatively low compared to earlier in the year, it induced negative effects on economic activities. These negative socio-economic impacts could lead to public pessimism about economic situations. To test the hypothesis, we computed several social and economic indicators, such as the consumer price index, unemployment rate, producer price index, and growth rate of GDP. The consumer price index had fallen since March and was in line with the previous year's level by the end of 2020 (Figure 5a). The unemployment rate also fell to 5.2 at the end of the year, which was lower compared to the high point of 6.2 at the beginning of the year (Figure 5b). The producer price index was lower than the corresponding period in the last year since February owing to the impact of the pandemic. However, the gap narrowed following May and reached only 0.4% in December of 2020 (Figure 5c). Meanwhile, the GDP, on the other hand, increased, reaching a growth rate of 3.2%, 4.9%, 6.5% in Quarters two, three, and four, respectively (Figure 5d). All major economic indicators showed largely positive economic trends in the China Mainland at Stage 5, leading us to speculate that the decrease in online public sentiment was probably not because of concerns about the impact of economic
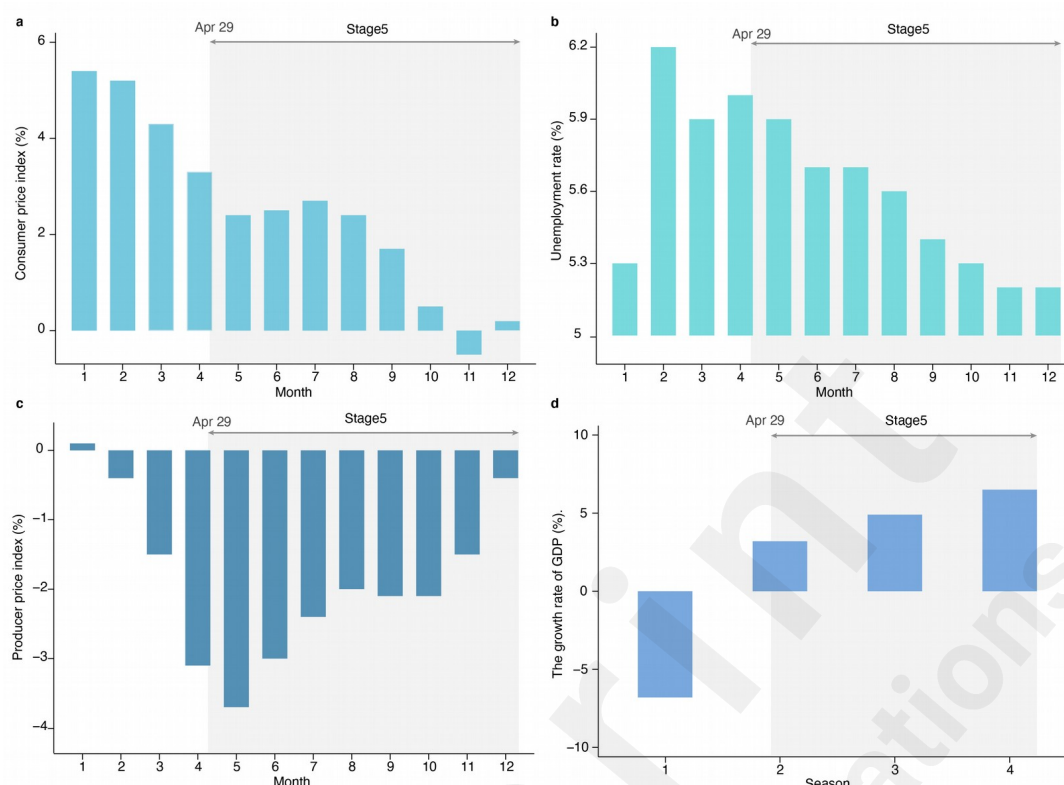
factors.

Figure 5. Major economic indicators in 2020 in the China Mainland including consumer price index (a), unemployment rate (b), producer price index (c), and GDP growth rate (d).

Concerns about the severity of the global pandemic
In Stage 5, although the China Mainland entered a recovery period from the pandemic, the global pandemic had been worsening. One is left to consider whether the decline of online public sentiment at Stage 5 was due to the increasing severity of the global pandemic. To find an answer, we compared the sentiment values with the number of newly confirmed COVID-19 cases worldwide in Stage 5. Although newly confirmed cases increased while sentiment values decreased in Stage 5, timelines of global newly confirmed cases of COVID-19 and sentiment values are out of sync. We calculated the rate of change of newly confirmed cases globally and sentiment values by taking a data point in a week. We first subtracted the data point one week earlier and then divided it by the data point one week earlier. We observed the rate of change of newly confirmed cases globally and sentiment values did not match (Figure 6b, r=.03, *P*=.84). This analysis indicates that the severity of the global pandemic may not be the reason for the decline of online public sentiment values in China in Stage 5.
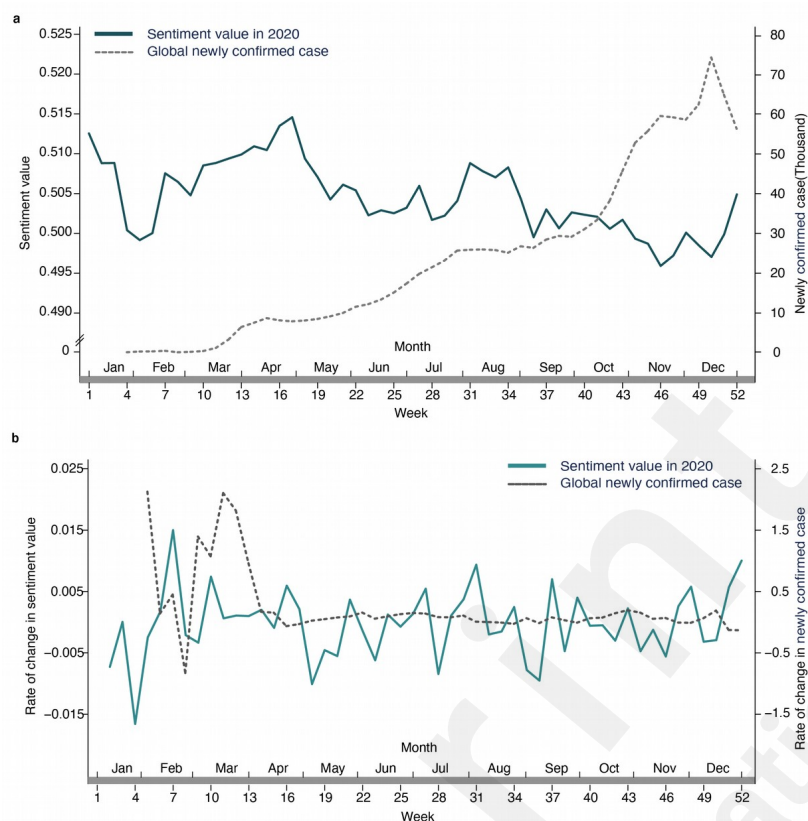
Figure 6. A comparison of global newly confirmed cases with online public sentiment values (a) and a comparison of the rates of change between newly confirmed cases globally and sentiment values (b).

Discussion

This study is the first to track online public sentiment in the China Mainland throughout the whole year of 2020 across the official five stages of the pandemic, from city lockdown to 'the new normal'. Such uninterrupted long-term tracking allows us to develop a comprehensive picture of the pandemic's impact on online public sentiment. Moreover, we analyzed the data from the corresponding period in the previous two years, excluding the influence of other possible confounding factors such as holidays. Our study identifies an interesting new phenomenon: a double descent of online public sentiment during the pandemic. The first descent verifies a strong negative effect of public sentiment at the outbreak of COVID-19. More importantly, the second descent illustrates the impact of the pandemic on online public sentiment during the recovery stage that has not been reported in previous literature.

In terms of the relationship between online public sentiment and the severity of the pandemic, there are two separate phases with the boundary at week 17. The first phase, Week 1 to Week 17, covers Stages 1- 4 defined by the white paper of the Chinese government. Our study corroborates previous studies, validating that public sentiment was strongly affected by the outbreak of COVID-19 and it was correlated with the severity of the pandemic [33-35]. Moreover, we observed that the public sentiment values increased as China brought the pandemic under control. Especially when the city of Wuhan was reopening, the online public sentiment index was even higher than that in the same period of the previous two years, showing a highly positive emotion in the general public after the recovery from the pandemic [16]. These consistencies support that the sentiment analysis of posts on Weibo correctly reflects public sentiment during the pandemic.

Public sentiment after Week 17, which was Stage 5 in the Chinese government's white paper on epidemic control, has not been investigated by previous studies. In this stage, the government had

brought the spread of the pandemic under control and socio-economic life had recovered substantially. We observed a surprisingly sustained decline of online public sentiment values in Stage 5, which differs from the decline in Stage 2 in several aspects. First, online public sentiment values in Stage 5 were decoupled from the severity of the pandemic. Second, the decline in Stage 2 only lasted three weeks while the decline in Stage 5 occurred for at least 34 weeks, with a much slower reducing rate. Third, the online public sentiment values in Stage 5 decreased as a descending spiral rather than a straight line. These characteristics indicate that the decline in Stage 5 is unlikely to be a real-time reaction induced by a single event, instead of reflecting a long-term emotional trend in the general public.

One may consider what causes such prolonged depression of public sentiment in Stage 5. After excluding possible economic reasons and comparing the extent of reduction between public sentiment values in Stage 2 and Stage 5, we can speculate that the decline could be a long-term effect of the emotional shock at the COVID-19 outbreak. Psychological studies have shown that people exposed to a traumatic event like an earthquake, tsunami, or terrorist attack, often struggle with symptoms of posttraumatic stress disorder (PTSD) [36, 37]. It is expected that such a severe pandemic as COVID-19 would induce PTSD among many groups, including infected patients [38, 39], medical workers [40, 41], those related to them, and people who are forced into isolation [42]. However, it is somewhat surprising that there is such a strong and long-last negative effect of the sentiment of this nature among the general population. This finding reflects the far-reaching public psychological impact of this unprecedented pandemic.

Despite the efficiency of using social media for analyzing online public sentiment, there remains a gap between the sentiment obtained from texts on the web and real emotion in the general population. Such a gap derives from the sampling bias between the users of the microblogging network and the population in the social group. Although Internet access has become widespread in China and Weibo is the largest online platform there, users of Weibo are not an unbiased sampling of the overall Chinese population because the internet population is relatively young and concentrated in metropolitan centers [43]. Moreover, there may also be a difference between the emotions people write in public media and their internal emotions. At the same time, our findings are based on Chinese social media data. At the current stage, the China Mainland is the only major world economy that has experienced a relatively complete cycle from early outbreak to the recovery of social-economic activities. It is unclear how public sentiment changes in other regions when they enter the recovery phase of the pandemic.

In summary, by tracking the online public sentiment for the whole year of 2020, we identified the long-term negative impact of COVID-19 on public sentiment, which shows the complexity and far-reaching impact of the pandemic on human emotions. This study's results suggest that from a public policy perspective, even when the pandemic had been controlled and social-economic activation is restored, decision-makers must still pay heed to public sentiment and take necessary action to alleviate the negative emotions induced by the pandemic.

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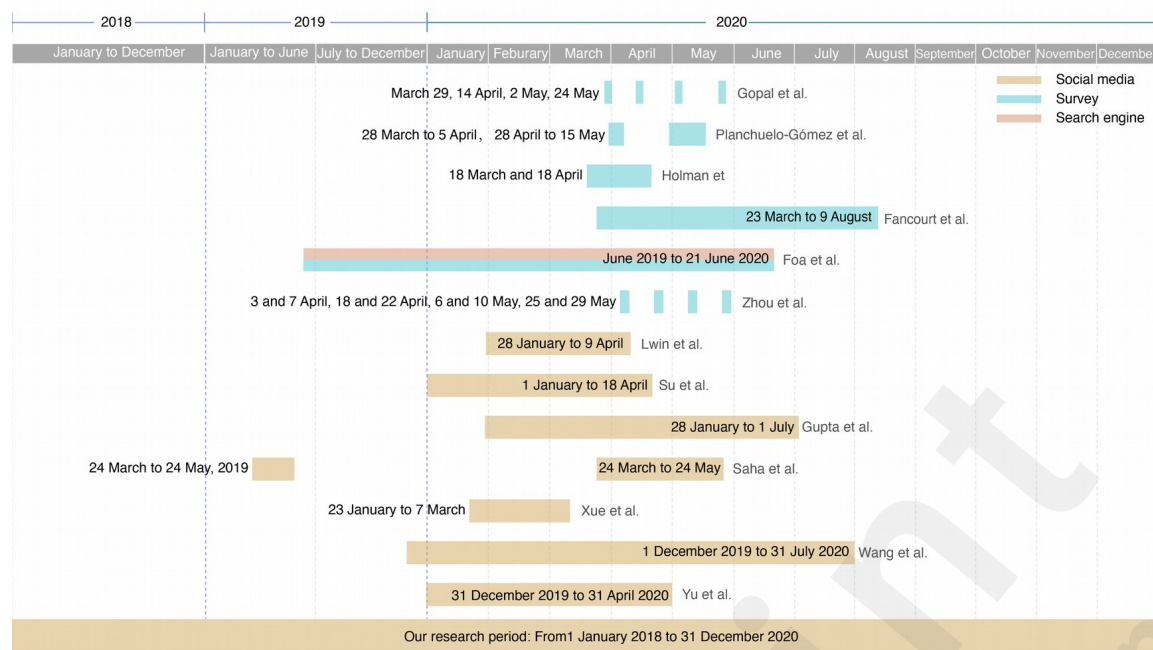
Figure 1. A literature map for studies on tracking public mental health during the pandemic. The horizontal axis labels the tracking time and different shading colors represent varying approaches to assess mental health.
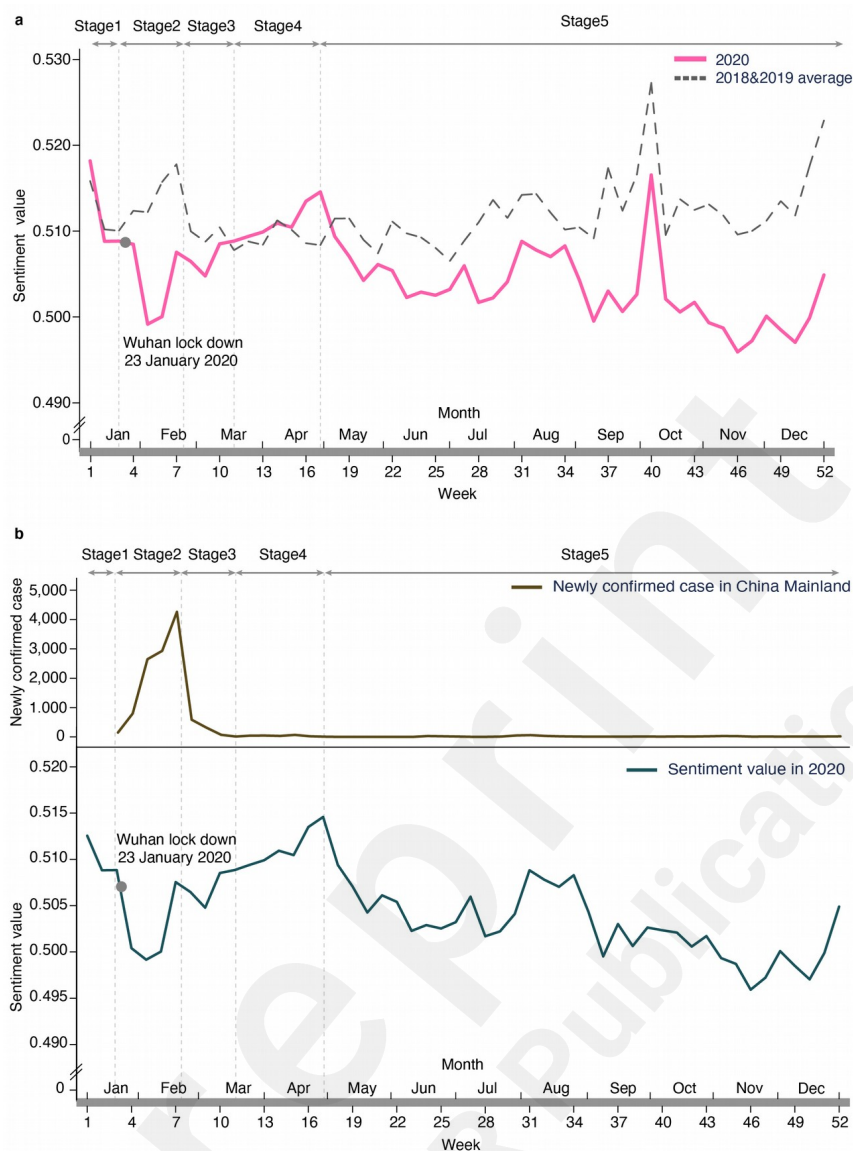
Figure 2. Online public sentiment values of Weibo over the last three years. (a) Online public sentiment values were plotted as a function of the week across the whole year. 2020: the solid line; averaged values of the previous two years: the dashed line. (b) Sentiment values in 2020 which exclude the holiday effects and number of newly confirmed cases per week for 2020.
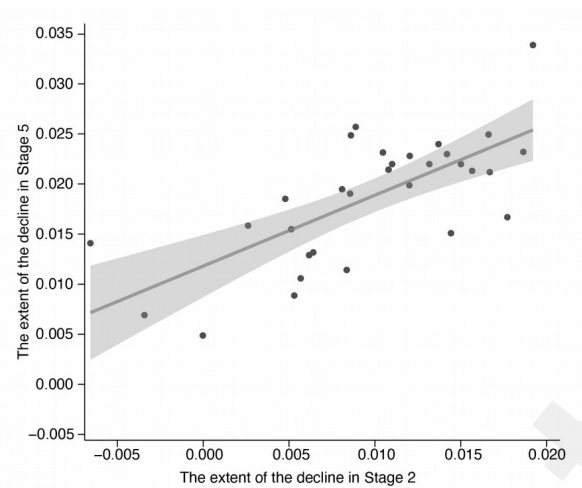
Figure 3. A correlation between the decline in online public sentiment values in Stage 2 with that in Stage 5. Black dots represent the extent of the decline of public sentiment values in each province in the China Mainland. The solid line represents a fitted linear curve of the extent of the decline in two stages (R^2=.50, *P*<.001, 95% CI 0.473–0.978).
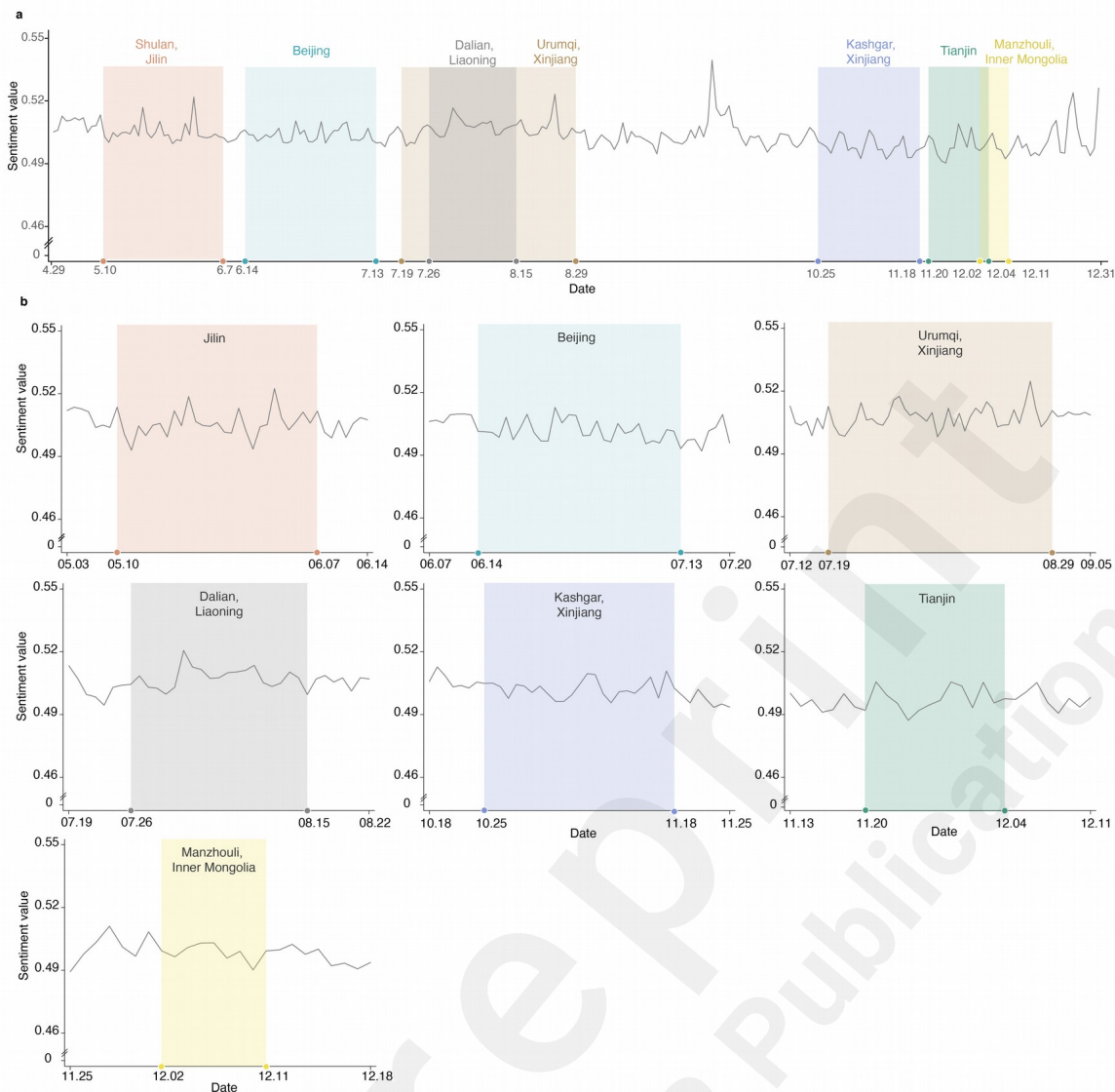
Figure 4. The effect of sporadic indigenous inflection cases in Stage 5. (a) national sentiment values in Stage 5. The time windows were labeled with underlay colors when the risk assessment level was upgraded to high risk in some areas. (b) local sentiment values in the provinces when the local risk assessment levels were upgraded.
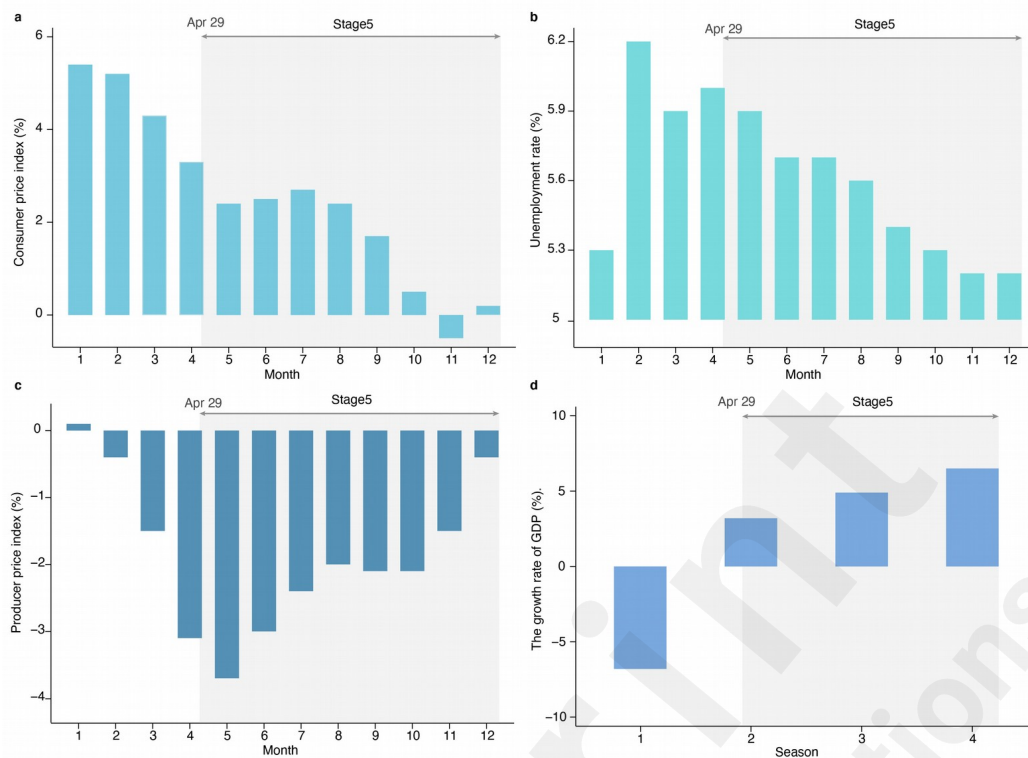
Figure 5. Major economic indicators in 2020 in the China Mainland including consumer price index (a), unemployment rate (b), producer price index (c), and GDP growth rate (d).
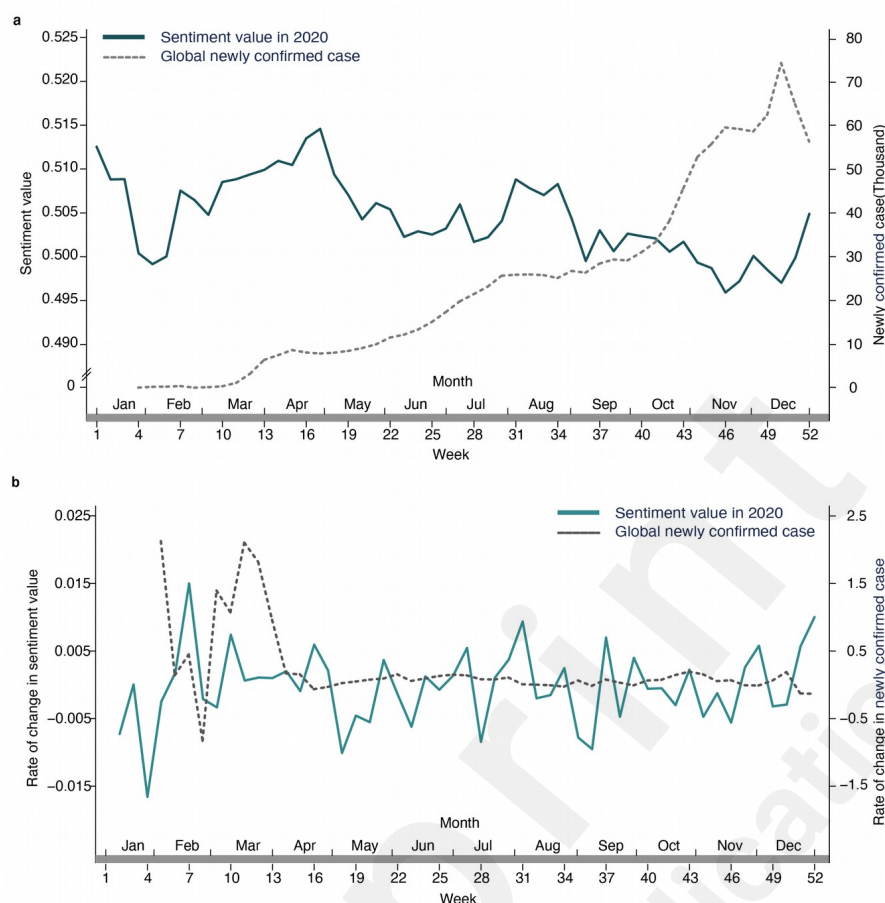
Figure 6. A comparison of global newly confirmed cases with online public sentiment values (a) and a comparison of the rates of change between newly confirmed cases globally and sentiment values (b).